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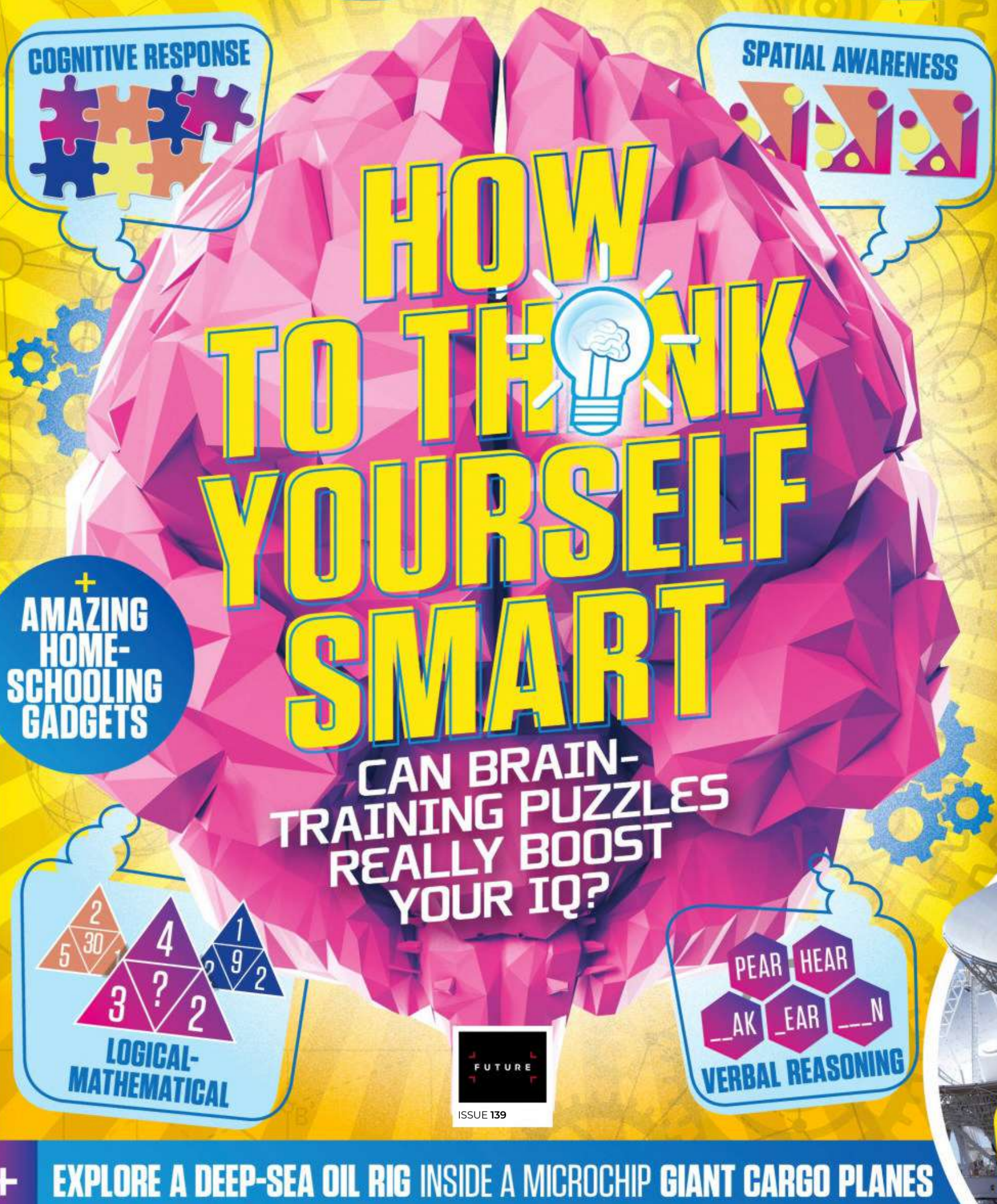

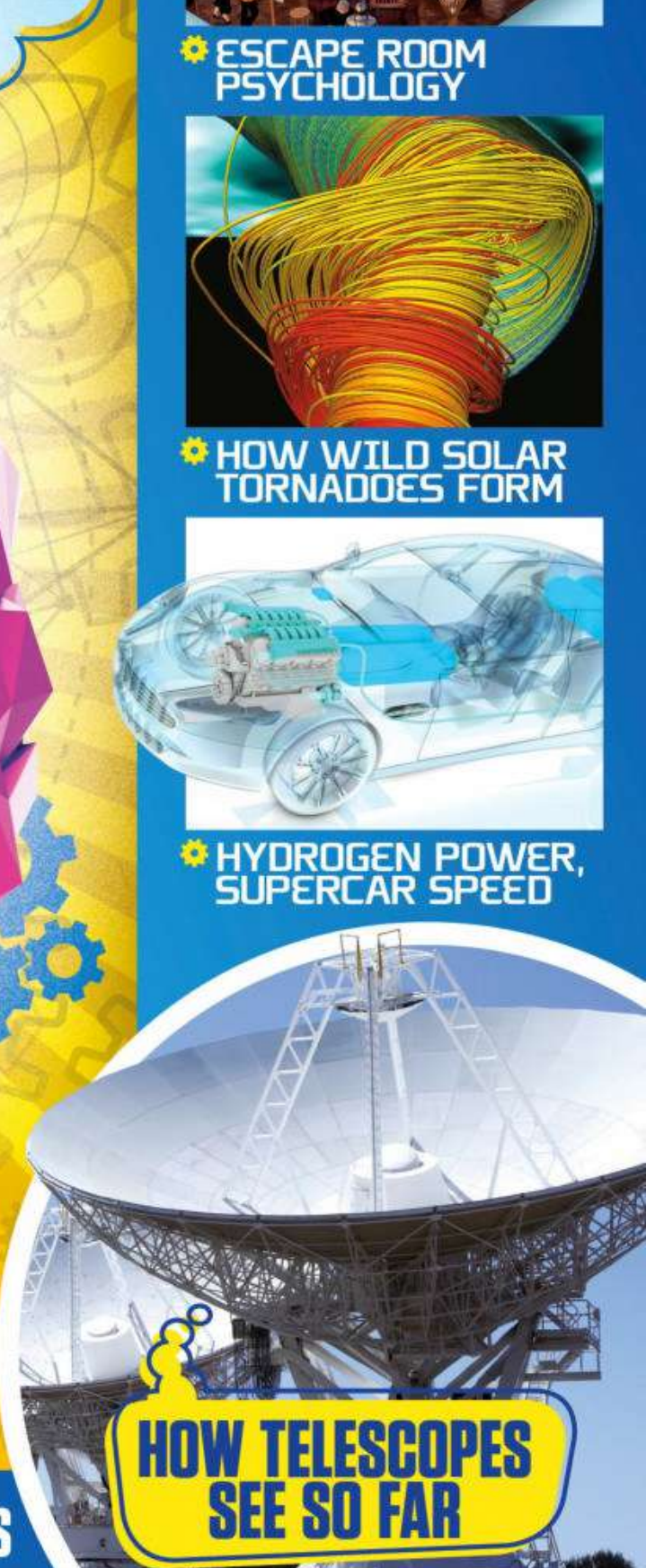

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D-Day Spitfire

THE NORMANDY INVASION

"You are about to embark upon the Great Crusade, toward which we have striven these many months. The eyes of the world are upon you..."
—Eisenhower, Letter to Allied Forces

Operation Overlord, commonly known as D-Day, was launched on 6 June 1944 with the Normandy landings. A 1,200-plane airborne assault preceded an amphibious assault involving more than 5,000 vessels. Nearly 160,000 troops crossed the English Channel on 6 June, and more than two million Allied troops were in France by the end of August.

Supermarine Spitfires were among the D-Day aircraft which provided air cover for the massive invasion, strafing strongholds and fighting off German bombers. As recreated on our Quickbuild models, the allies painted the plane's wings with stripes to ensure the Allied aircraft were not targeted by friendly-fire in all the chaos of war. This was kept secret and only revealed to the troops who would take part just days ahead of the first waves.

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"Fluid intelligence grows and grows and grows up to around the 20s"

How to think yourself smart, page 18

Meet the team...

Nikole
Production Editor
Uncover the mysteries of the language of the pharaohs and decode ancient Egyptian symbols on page 40.

Scott
Staff Writer
From see-through frogs to immortal jellyfish, discover Earth's strangest species – and why they've evolved this way – on page 28.

Baljeet
Research Editor
Telescopes are able to see in many wavelengths that human eyes cannot. See how this reveals unseen sights of the universe on page 50.

Duncan
Senior Art Editor
On page 62, learn about the circuits that lie at the heart of every piece of technology you own – from your toaster to your smartphone.

Ailsa
Staff Writer
Escape rooms trigger many responses in the brain, but can we channel our minds for success? Join us in one on page 42.

There are pros and cons to growing up and getting older. Your memory might worsen as you age, but you're probably better able to make good decisions than when you were younger. As a scatterbrained youngster you might still have a lot to learn – but you'll soak information up like a sponge, adapting and acquiring knowledge far quicker than any grown-up. Why is that? Is there anything we can do to improve our brains – to think ourselves smart? In this issue of **How It Works** we examine what intelligence is, how it evolves throughout our lives, how we can improve our IQ, and whether brain-training exercises work. Enjoy the issue!

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Ben Editor

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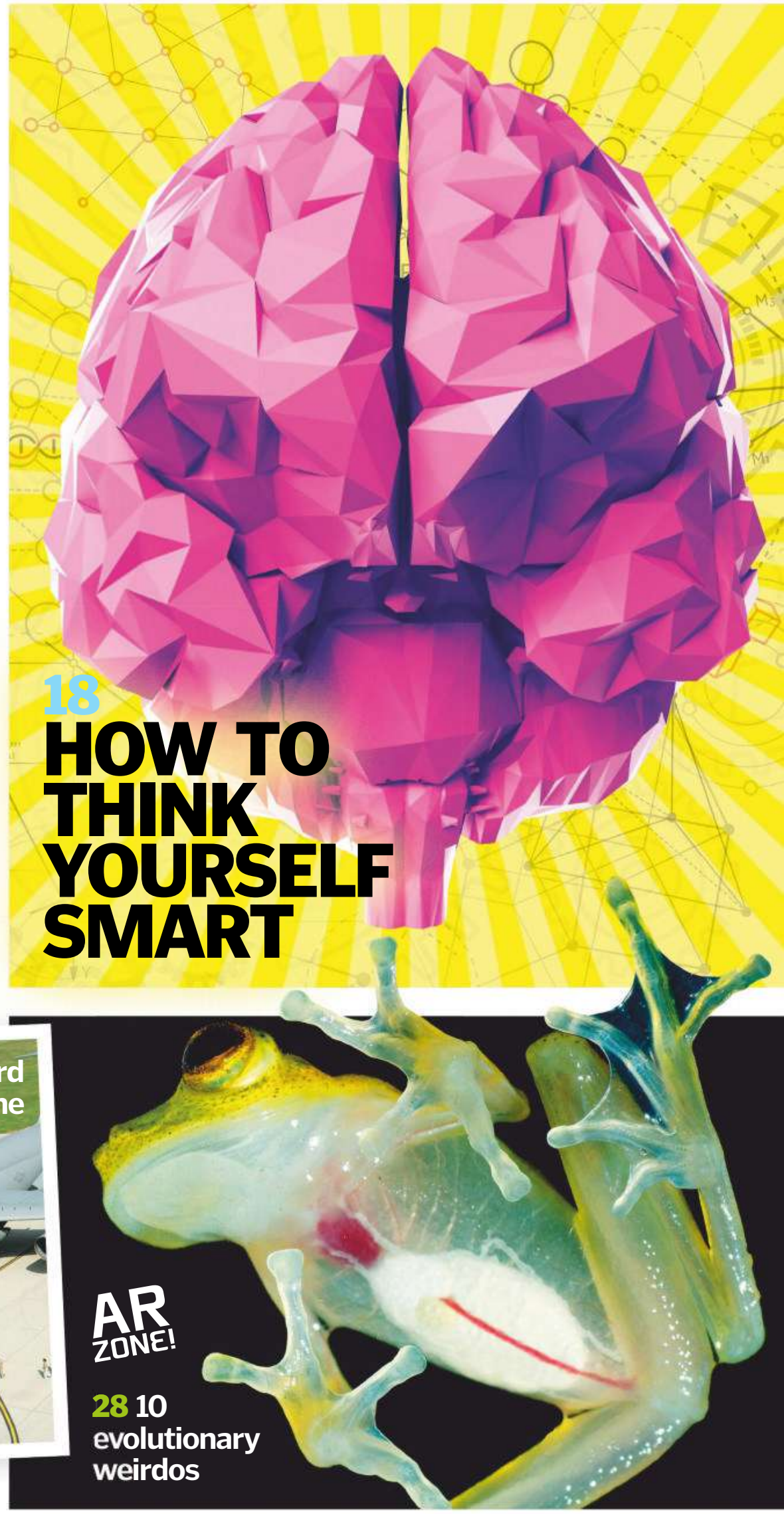

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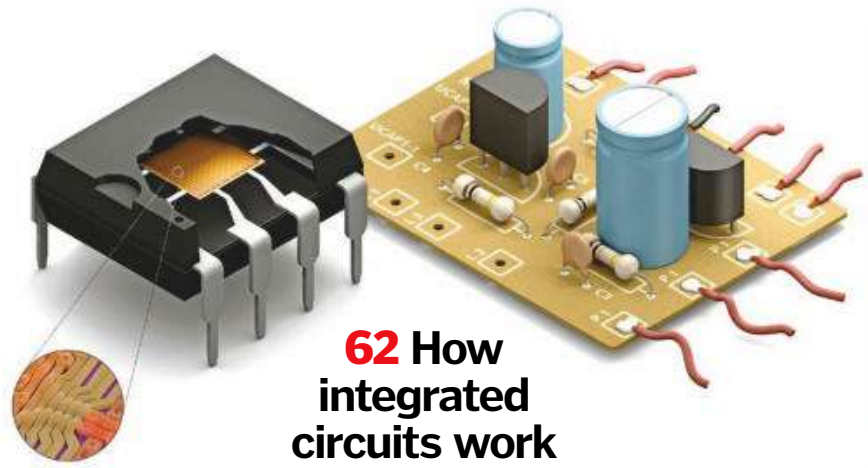
MEET THIS ISSUE'S EXPERTS...

Jo Elphick
Jo is an academic lawyer and lecturer specialising in criminal law and forensics. She is also the author of a number of true crime books.

Mark Smith
A technology and multimedia specialist, Mark has written tech articles for leading online and print publications for many years.

Andy Extance
Andy is a freelance science writer based in Exeter, UK. He previously worked in early stage drug discovery research, followed by a brief stint in silicone adhesive and rubber manufacturing.

Dr Andrew May
Andrew has a PhD in astrophysics and 30 years in public and private industry. He enjoys space writing and is the author of several books.



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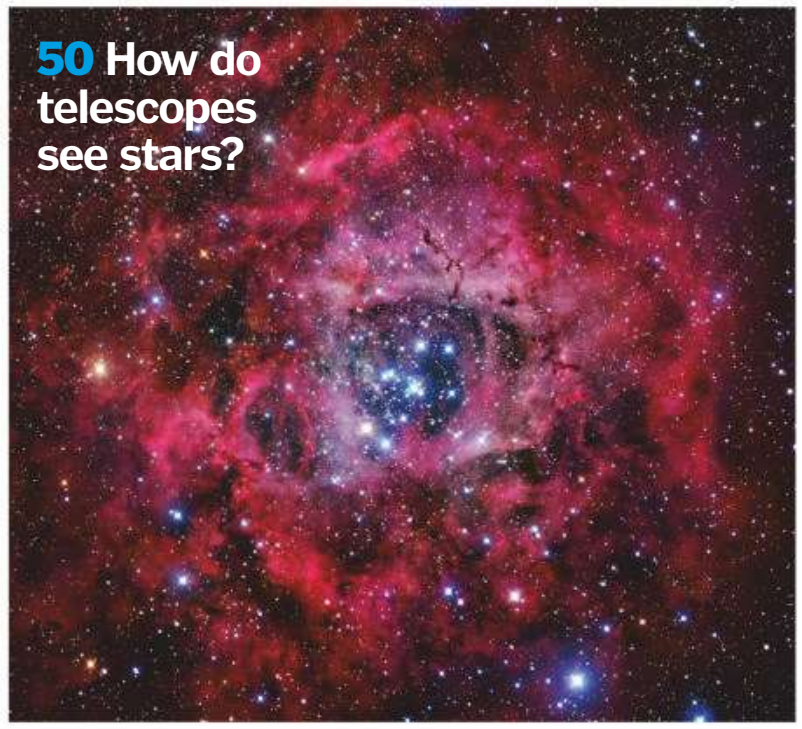

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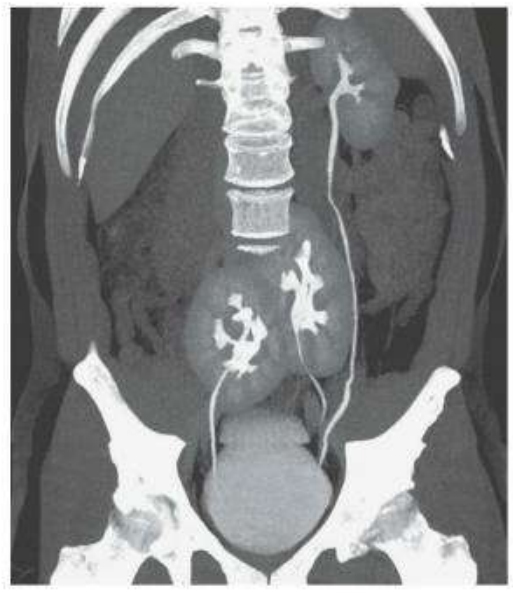

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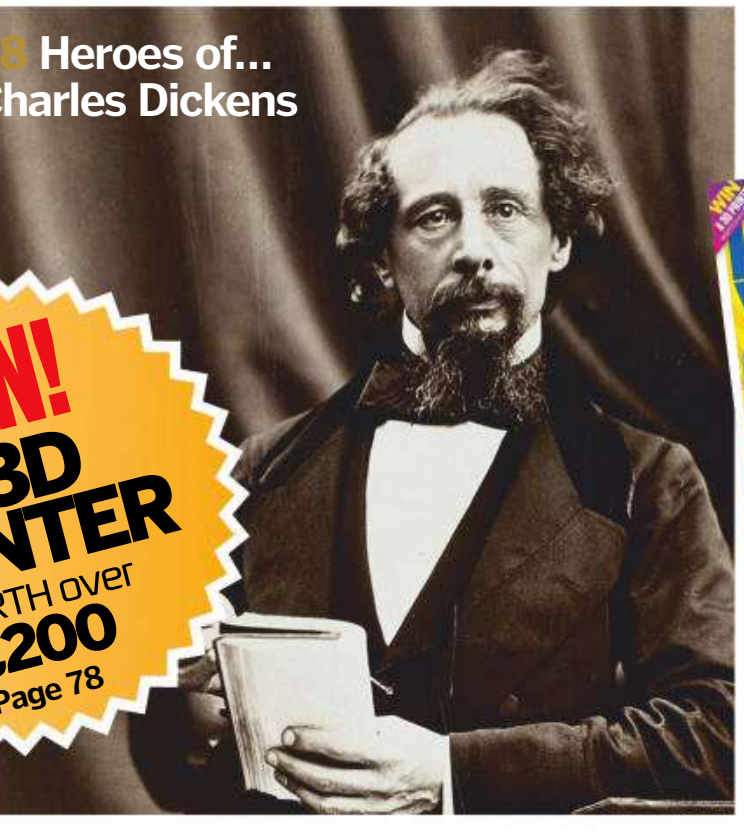

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Amy Grisdale
Volunteer animal worker Amy has an enormous breadth of experience on animal conservation projects. She specialises in writing about environmental topics.

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WINGS LIKE A SHIELD OF GLASS

Found only in the eastern half of the United States, cicadas have a disappearing act whereby they vanish from the world for years. Young cicada nymphs spend many years in underground burrows before finally emerging as adults. In the case of the 17-year periodical cicada species, this can take a long time. Finally getting their hands on these elusive insects, researchers have recently found that a chemical coating on their glass wings gives them the ability to repel water and even kill microbes.

WALL OF SAND

Sweeping across the Namib Desert in Namibia, this wall of sand – which can reach heights of up to 15 metres – engulfs everything in its path. Sand and dust storms occur mainly in dry, arid regions around the world. High winds whisk desert sand into a frenzy and build it into an engulfing wall. These winds are typically caused by thunderstorms, lifting the sand and dry soil and throwing it into the atmosphere. If the winds are strong enough, sand can be carried for hundreds or even thousands of kilometres. On its blustery journey, dust particles held in the lowest layer of Earth's atmosphere also precipitate into the sandstorm, allowing it to grow further.

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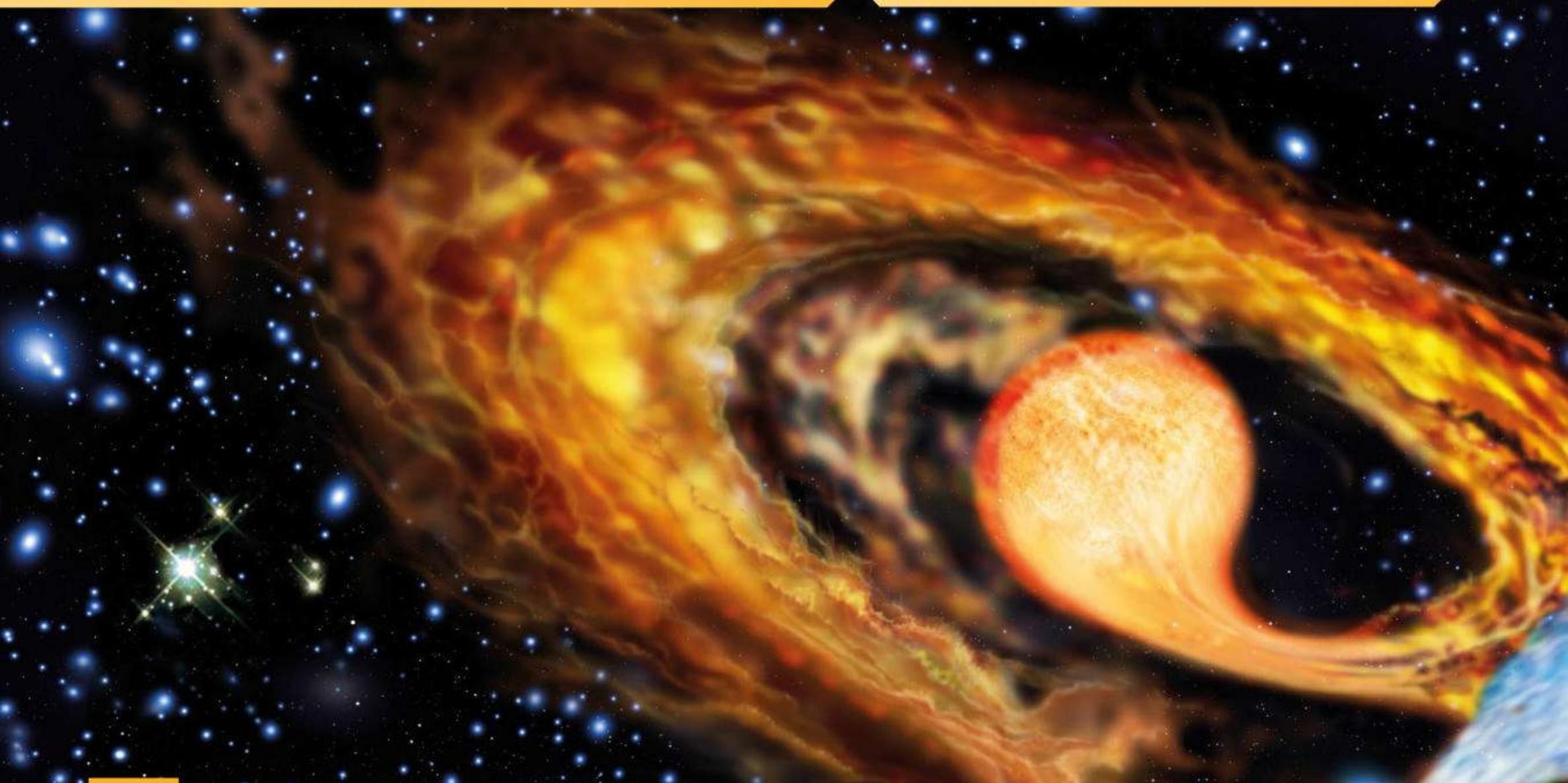
With over 14 million global monthly users, **Live Science** makes every day a little more interesting by illuminating the fascinating world around us. For the science geek in everyone, **Live Science** breaks down the stories behind the most interesting news and photos on the internet.



SPACE

Super-fast pulsar feeds on stellar companion

Words by **Gemma Lavender**

China's Five-hundred-meter Aperture Spherical Telescope (FAST) has uncovered the first known pulsar in Messier 92, a globular star cluster roughly 27,000 light years away from Earth in the constellation of Hercules. The swiftly spinning and pulsating object, which goes by two names – PSR J1717+4307A and M92A – forms one part of an eclipsing binary system in which it is siphoning material from a stellar companion.

A research team led by Zhichen Pan and Di Li from the National Astronomical Observatories of the Chinese Academy of Sciences (NAOC), which operates FAST – the world's largest radio telescope – has shown that M92A spins at a rapid speed of 316.5 rotations per second and co-orbits a star much lighter than our Sun, weighing in at 0.18 solar masses.

Using FAST the researchers observed two eclipsing events in the binary system, when one object passed in front of the other from Earth's point of view. One eclipse lasted around 5,000 seconds, and the second, which arrived between 1,000 and 2,000 seconds later, lasted for 500 seconds. M92A is known as a millisecond pulsar, a souped-up version of the slightly slower moving pulsar. Millisecond pulsars are highly magnetised neutron stars which pirouette rapidly at speeds less than 30 milliseconds.

Ordinary pulsars spring into existence at the end of a massive star's life, peaking as a supernova explosion that leaves behind a stellar corpse known as a neutron star in its dusty wake. The neutron stars left behind are small, weighing in at a mass that's equivalent to anywhere from one to several Suns, crammed into a diameter of a mere 20 to 24 kilometres. Yet what they lack in size they make up for in speed, completing several rotations per second.

If there is a magnetic field lurking around the neutron star, charged particles coming from the star itself become snagged, causing the star to blast electromagnetic radiation in a lighthouse-like beam every few seconds or less. These flashing, magnetic neutron stars are known as pulsars.

Millisecond pulsars, however, move much more quickly, powering hundreds of rotations per second by chewing on gas from a companion star that survived the

© European Space Agency & Francesco Ferraro (Bologna Astronomical Observatory)

An artist's impression of a millisecond pulsar and its stellar companion

supernova explosion, spilling material into a disc around the neutron star before falling onto it. During this process the system is visible as an X-ray binary. The neutron star then emerges as a millisecond radio pulsar when the accretion is over.

In globular clusters like Messier 92, things work a bit differently – stars are so tightly packed together that it's easier for ancient neutron stars to interact with other stars, allowing normal stellar binaries to be made.

In the case of M92A, the pulsar hasn't found it too difficult to siphon material from its stellar companion, earning itself the reputation of being likened to a 'redback spider' (*Latrodectus hasseltii*) – highly venomous Australian arachnids that often eat their male companions.

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HISTORY

'Blank' Dead Sea Scrolls reveal hidden letters

Words by **Laura Geggel**

Four Dead Sea Scroll fragments, previously thought to be blank, are anything but: detailed imaging has revealed that these ancient pieces of parchment contain letters, sewn thread, ruled lines and even a discernible word, new research finds.

The finding almost went unnoticed until Joan Taylor, a professor of Christian origins and Second Temple Judaism at King's College London, took a magnifying glass to these fragments and noticed that there was a 'lamed', the Hebrew letter for 'L', written on one of them. At the time Taylor said she thought that she "might be imagining things. But then it seemed maybe other fragments could have very faded letters too."

Taylor's hunch paid off. One of the four fragments had four lines of text, with a total of 15 to 16 completely or partially preserved letters. One word, 'Shabbat', the Hebrew word for 'Sabbath', is clearly visible, and this clue, as well as several other letters, suggest that this fragment might be from the biblical book of Ezekiel (46:1-3).

The Dead Sea Scrolls consist of more than 900 manuscripts written by an ancient Jewish sect known as the Essenes. Since the scrolls' discovery in the Qumran Caves of the West Bank in 1946, scholars have pored over the texts, which include versions of the Hebrew Bible, calendars, astronomical observations and community rules.

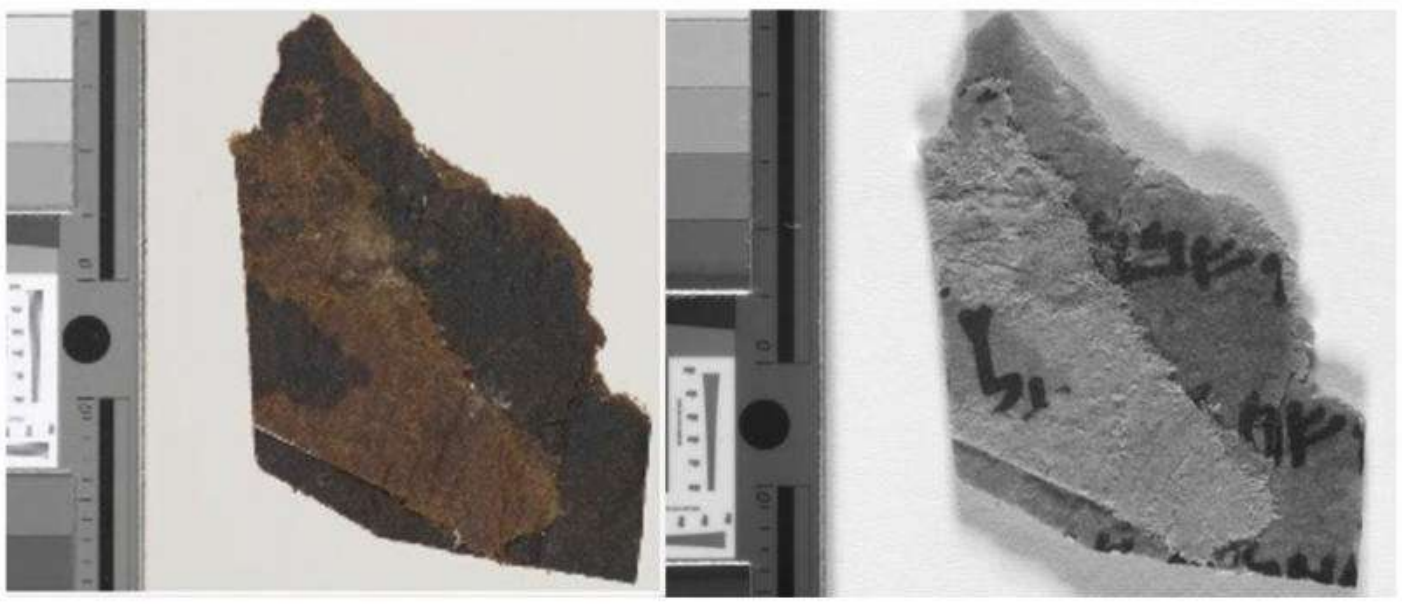
Although some parchments touted as Dead Sea Scrolls are forgeries, the fragments studied in this experiment are the real deal. These fragments were discovered during the official excavations of the Qumran Caves, and were not channelled through the antiquities market.

This collection of fragments was then donated to the University of Manchester in 1997, but received little attention – until now, when Taylor spied the Hebrew letter. To see if any of the other fragments had text, she photographed all the pieces in the collection that were over one centimetre long – 51 in total – that appeared blank to the naked eye.

Taylor used multispectral imaging, a technique that uses various wavelengths on the electromagnetic spectrum, such as infrared, to capture images of hard-to-see figures, such as the carbon-based ink on the scrolls. In the end she and her colleagues found that some fragments had ruled lines or vestiges of letters, but only four fragments had Hebrew or Aramaic text. One of those pieces was from the sewed edge of a parchment scroll and had a few letters on it.

"With new techniques for revealing ancient texts now available, I felt we had to know if these letters could be exposed," Taylor said. "There are only a few on each fragment, but they are like missing pieces of a jigsaw puzzle you find under a sofa."

"This fragment might be from the biblical book of Ezekiel (46:1-3)"



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The Hebrew word 'Shabbat' is visible in the upper-right-hand corner. A lamed – the letter 'L' in Hebrew – is written on the left side

IN ASSOCIATION WITH LIVESCIENCE

A wooden bit for goat kids or lambs to prevent them suckling their mother, as the milk was processed for human consumption, radiocarbon dated to the 11th century

HISTORY

Rare Viking treasure found on mountain trail

Words by **Mindy Weisberger**

Archaeologists recently documented a rare treasure trove of Viking Age objects littering a long-forgotten mountain pass, including the remains of a dog wearing its collar and leash. As climate change melts Norway's glaciers, pockets of history hidden for centuries or millennia are finally seeing the light of day. Melting along a high-altitude trail in the Lendbreen glacier has revealed hundreds of artefacts dating to the Viking Age, the Roman Iron Age and even the Bronze Age. Remarkably well-preserved items littered the winding path, including clothing and shoes, a variety of tools and riding gear and animal bones and dung. They offer clues about daily life and hint at the challenges and importance of mountain travel in this region. The ice patch at the Lendbreen site extends from about 1,690 to 1,920 metres above sea level, and the mountain pass rises to nearly 1,973 metres above sea level.

In the new study scientists documented discoveries that appeared between 2011 and 2015, preserved by the dry, frozen climate and protected by layers of ice before being exposed. Among the objects were shoes made of hide, a woven mitten and more than 50 pieces of fabric, a walking stick inscribed with runes, a wood-handled knife, horseshoes and sled pieces and bones from pack horses. "The preservation of the objects emerging from the ice is just stunning," said one of the scientists, Espen Finstad.

Dead animals and broken tools were likely abandoned along the path by the travellers, while tools in good condition may have simply been lost. The presence of usable clothing among the discarded objects is more puzzling, but these items may have been thrown away by people who were suffering from severe hypothermia, which can cause irrational behaviour.

"Remarkably well-preserved items littered the winding path"

Carbon dating of approximately 60 objects indicated that the pass was actively used from around 300 to 1500 CE. Some objects, such as a ski and an arrow, dated to the Bronze Age, and several artefacts were even older. But the items that were most abundant dated to around 1000 CE – the Viking Age – suggesting that the mountain pass was busiest during this period.

Unlike many other ancient mountain passes that are known from the Alps and the Himalayas, this route was likely busiest when snow and ice were abundant, as the route would have been difficult for pack animals and sleds to navigate when rocks were bare.

By sifting through all the objects, scientists reconstructed how people used the path and how that changed over time. What was once a high-traffic roadway during the Viking Age waned in popularity and was all but abandoned by the 16th century, possibly due to climate change-related melting, economic upheaval and the arrival of pandemics from Europe.

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SPACE

Astronomers discover closest black hole to Earth

Words by **Hanneke Weitering**

A new-found black hole may be the closest black hole to Earth, and you can spot its cosmic home in the night sky without a telescope. The black hole, which is lurking 1,000 light years from Earth in the southern constellation of Telescopium, belongs to a system with two companion stars that are bright enough to observe with the naked eye. But you won't be able to see the black hole itself; the massive object has such a strong gravitational pull that nothing, not even light, can escape it.

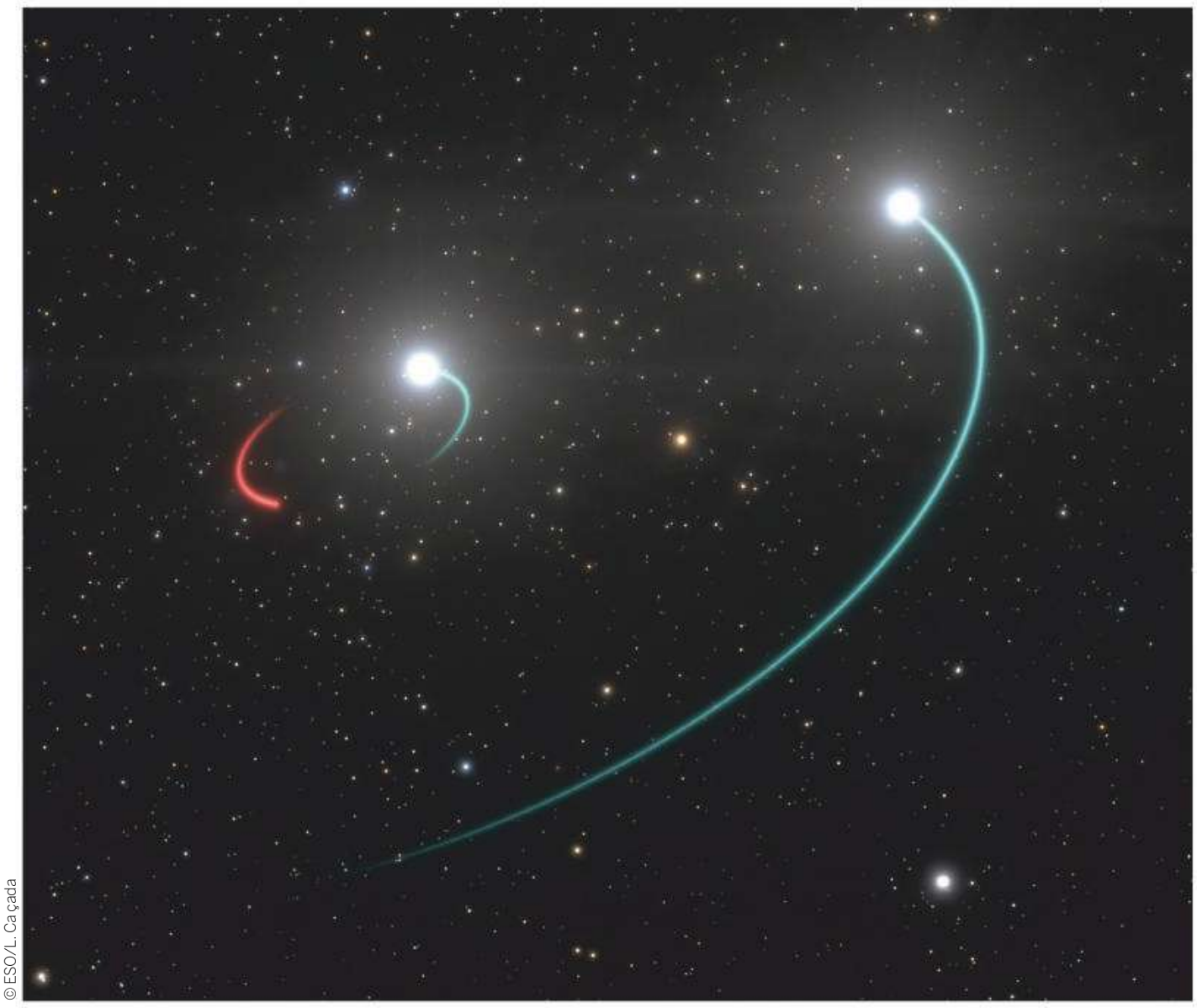
Astronomers discovered this black hole while studying what they thought was just a binary star system, or two stars that orbit a common centre of mass. They were using the MPG/ESO 2.2-metre telescope at the La Silla Observatory in Chile to observe the binary, known as HR 6819, as part of a broader study on double star systems. When they analysed their observations, the researchers were shocked to learn that a third object was hiding in the system: a black hole.

Although the astronomers could not directly observe the black hole, they were able to infer its presence based on its gravitational interactions with the other two objects in the system. By observing the system for several months they were able to map out the stars' orbits and figure out that another massive, unseen object must be acting in the system.

The observations also showed that one of the two stars orbits the invisible object every 40 days, while the other star hangs out by itself at a much greater distance from the black hole. They calculated that the object is a stellar-mass black hole, a black hole that forms from the collapse of a dying star, that's about four times the mass of the Sun. "An invisible object with a mass at least four times that of the Sun can only be a black hole," said Thomas Rivinius, who led the new study. "This system contains the nearest black hole to Earth that we know of."

The black hole in HR 6819 is one of the first stellar-mass black holes found in our galaxy that does not release bright X-rays while violently interacting with its companion stars, and the discovery could help researchers find other similarly 'quiet' black holes in the Milky Way.

An artist's impression shows the orbits in the HR 6819 triple system, which consists of a binary star pair in which the stars (blue) orbit a black hole (red)



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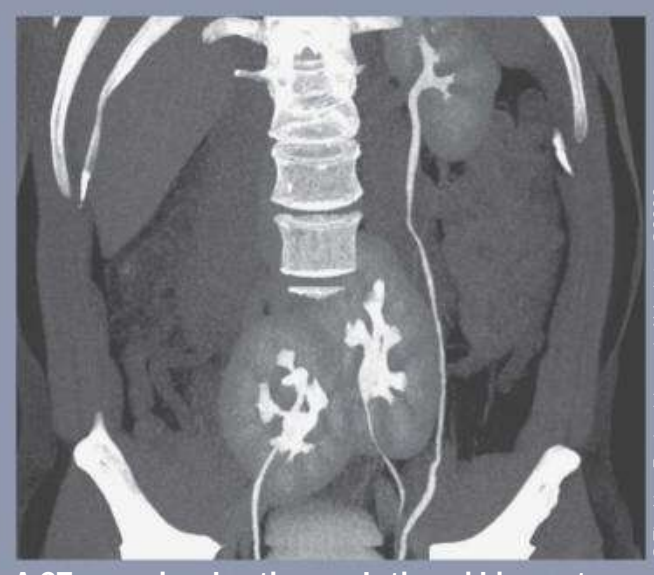

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A CT scan showing the man's three kidneys: two kidneys are fused at the pelvis

HEALTH

Man's back pain leads to extra kidney discovery

Words by **Rachael Rettner**

When a Brazilian man went to the doctor complaining of lower back pain, his doctors got a surprise: they discovered that the man had not two, but three kidneys – a very rare condition.

To figure out the cause of the 38-year-old man's severe pain, doctors at the Hospital do Rim in São Paulo, Brazil, initially performed a CT scan to evaluate the area. The scan showed the man had a herniated or 'slipped' disc, a common condition in which part of a cushion-like disc between the spinal vertebrae moves out of place.

But it wasn't just the herniated disc that caught the doctors' attention. They couldn't help but notice that the man had an unusual anatomical feature. Instead of the usual two kidneys seen in a typical person, the man had three: a normal-looking kidney on his left side and two fused kidneys located near the pelvis. The man didn't have any symptoms of a kidney problem, and the organs appeared to be working normally.

Having three kidneys is rare, with fewer than 100 cases reported in medical literature. The condition is thought to arise during embryonic development when a structure that typically forms a single kidney splits in two.

Because the condition doesn't usually cause symptoms, people typically don't know they have it unless it's discovered by accident through unrelated medical tests. The man didn't need any medical attention for his extra kidney, but he did receive oral painkillers for his back pain.

ANIMALS

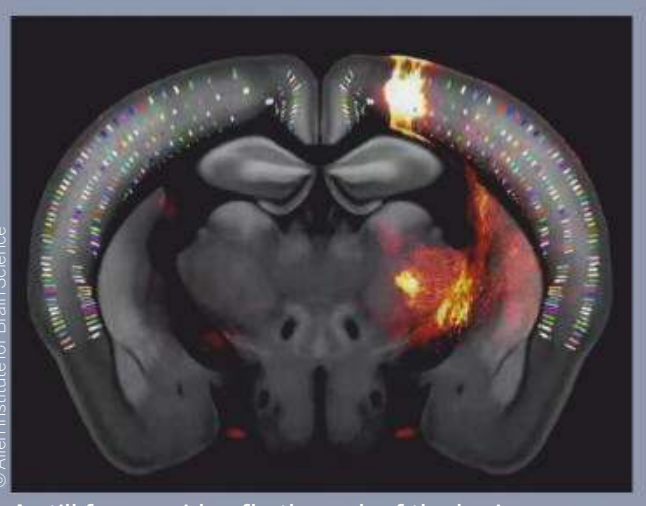
3D map traces neurons in a mouse brain

Words by **Rafi Letzter**

This flickering, ghostly image is the most detailed view of a mouse brain ever seen. Researchers at the Allen Institute for Brain Science have been painstakingly recording every brain cell and every connection between the neurons in mice for the past several years. The result represents major progress since an earlier, simpler map they released in 2016. The now-complete map encompasses about 100 million cells.

The project aims to do for neuroscience what whole-genome sequencing did for biology in the 1990s: create a common, standardised mouse brain that all researchers working on mice can reference. Typically researchers trace connections between brain cells using thin slices of tissue that can be imaged and explored layer by layer. To build a comprehensive three-dimensional map, the Allen Institute team instead broke the mouse brain into 'voxels' – 3D pixels – and then mapped the cells and connections within each voxel.

The result comprises an 'average' of the brains of 1,675 laboratory mice to make sure the map was as standard as possible. Mice are common 'model organisms' in neuroscience. Their brains have fairly similar structures to humans', they can be trained, they breed easily and researchers have already developed robust understandings of how their brains work. The hope is that the map will bring that understanding to a new level.



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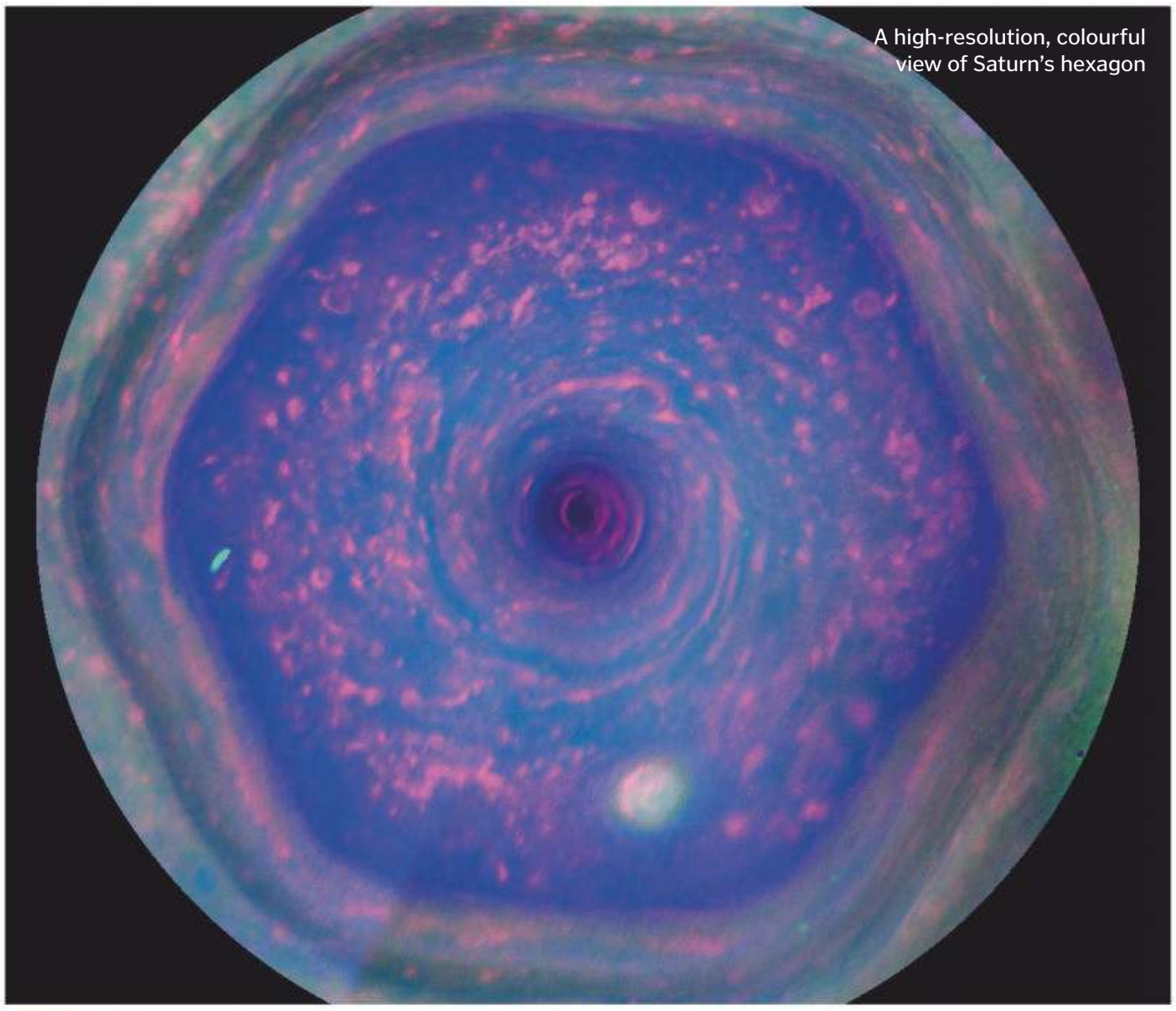
A still from a video fly-through of the brain map shows a slice of mouse brain



A high-resolution, colourful view of Saturn's hexagon

© NASA/JPL-Caltech/SSI/Hampton University

SPACE

Weird Saturn hexagon covered in 'sandwich-like' haze

Words by **Chelsea Gohd**

There's an extensive system of haze layers in the bizarre hexagon on Saturn, a new study has found. 'Saturn's hexagon' is a swirling maelstrom at the planet's north pole that, as its name implies, has an odd, hexagonal shape. The hexagon is an ever-present cloud pattern that 'stands' as tall as an enormous, whirling tower on the planet. The phenomenon was first discovered in 1980 by NASA's Voyager spacecraft and was later imaged in exquisite detail by the Cassini spacecraft, which orbited the planet from 2004 to 2017.

Now in a new study, scientists with the Planetary Science Group at the University of the Basque Country used images from Cassini and the Hubble Space Telescope to show that Saturn's hexagon is more than just a geometric oddity. The feature has its own system of hazes layered on top of one another.

In 2015 Cassini's main camera snapped high-resolution images of Saturn that revealed the hazes above the clouds in the hexagon. 15 days later the Hubble Space Telescope also took a look at the planet and its strange hexagon. Using these images the team was able to understand more about the layers of hexagon hazes spotted by Cassini.

"The Cassini images have enabled us to discover that, just as if a sandwich had been formed, the hexagon has a multi-layered system of at least seven mists that extend from the summit of its clouds to an altitude of more than 300 kilometres above them," said Agustín Sánchez-Lavega, who led the study.

The researchers discovered that each of these haze layers is approximately between 7 and 18 kilometres thick. The team thinks that because of the drastic freezing temperatures in Saturn's atmosphere – which range from minus 120 degrees to minus 180 degrees Celsius – there are likely frozen crystalline particles made up of butane, acetylene or even propane in the cloud structure.

While Saturn's hexagon feature is still not completely understood, by understanding phenomena like Saturn's hexagon better, researchers hope to better understand not only this strange cloud pattern on Saturn, but also atmospheric phenomena that happen here on our home planet.

HEALTH

COVID-19 pandemic could play out for two years

Words by **Rachael Rettner**

Although no one yet knows what the future holds for COVID-19, most experts seem to agree that it isn't going away any time soon. A new report estimates that the pandemic will likely last about two years. The report, from researchers at the University of Minnesota, draws on information from eight previous flu pandemics going back to the 1700s and incorporates data from the current COVID-19 pandemic.

The researchers note that the new coronavirus, called SARS-CoV-2, is not a type of influenza, but it shares some similarities with pandemic flu viruses: both are respiratory viruses to which the population has little to no previous immunity, and both can spread when people don't have symptoms. Still, the virus causing COVID-19 appears to spread more easily than the flu, and asymptomatic transmission may account for a greater proportion of COVID-19's spread compared with the flu.

Given how easily SARS-CoV-2 spreads, about 60 to 70 per cent of the population may need to be immune in order to achieve 'herd immunity' and bring a stop to the pandemic. This will take time, since a relatively small fraction of the US population seems to have been infected so far – although infection rates vary by location – according to studies looking at antibodies to SARS-CoV-2 in blood samples.

The report then outlines three potential scenarios for how the COVID-19 pandemic could play out: in the first scenario the current wave of COVID-19 cases is followed by a series of smaller waves, or 'peaks and valleys', that occur consistently over a one- to two-year period, but gradually diminish sometime in 2021.

Another possibility is that the initial wave of COVID-19 in the spring of 2020 is followed by a larger wave of cases in the autumn or winter, as happened with the flu pandemic of 1918. Subsequently, one or more smaller waves could occur in 2021.

Finally, the initial spring wave of COVID-19 could be followed by a 'slow burn' of transmission and cases that doesn't follow a clear wave pattern, the authors said. During new 'waves' of cases, areas may need to periodically reinstate and relax mitigation measures, such as social distancing, to prevent the health care system from being overwhelmed with cases.

Regardless of which scenario unfolds, we're not out of the woods yet: "we must be prepared for at least another 18 to 24 months of significant COVID-19 activity, with hot spots popping up periodically in diverse geographic areas."

People sit on designated seats to ensure social distancing inside a train in Palembang, Indonesia, 20 March 2020

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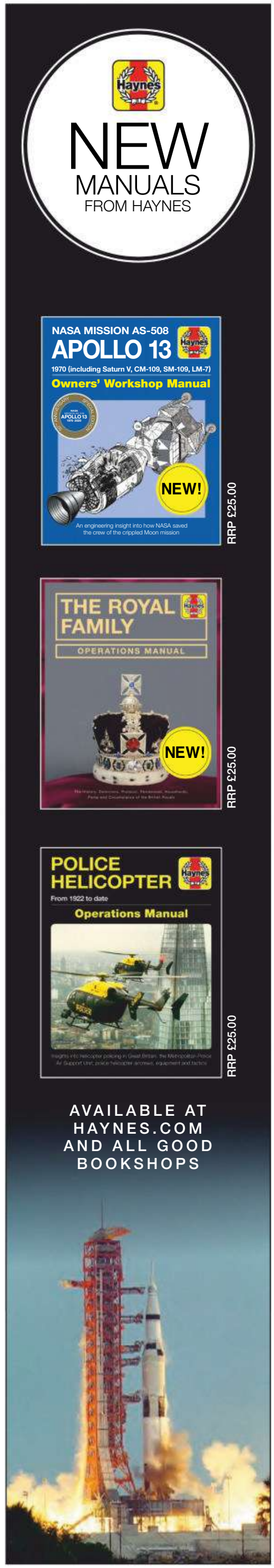


WISH LIST

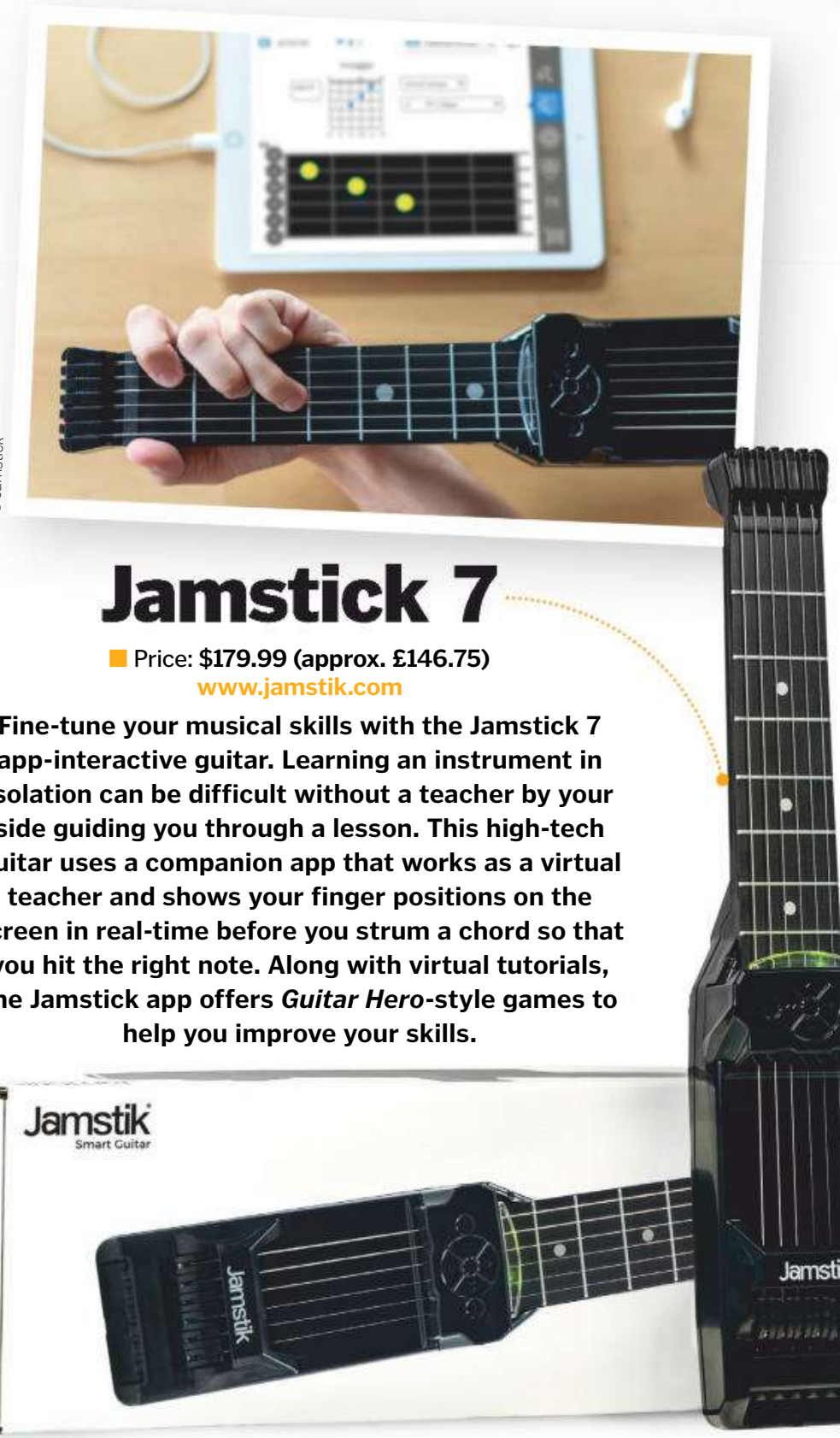
The latest **home schooling** gadgets

MP Cadet 3D printer

Price: **$249.99 (approx. £203.80)**
www.monoprice.com

If you've got a budding engineer at home then the MP Cadet 3D printer may be a great tool to introduce them to the world of digital design and the frontier of 3D printing. Arriving fully assembled and WiFi-enabled, this printer is a straightforward product for beginners. The free companion app is filled with downloadable models for you to print, and with built-in automatic levelling, beginners don't have to worry about manually adjusting the height of the surface models print on.

© Monoprice



© Jamstick

Jamstick 7

Price: **$179.99 (approx. £146.75)**
www.jamstik.com

Fine-tune your musical skills with the Jamstick 7 app-interactive guitar. Learning an instrument in isolation can be difficult without a teacher by your side guiding you through a lesson. This high-tech guitar uses a companion app that works as a virtual teacher and shows your finger positions on the screen in real-time before you strum a chord so that you hit the right note. Along with virtual tutorials, the Jamstick app offers *Guitar Hero*-style games to help you improve your skills.

Frozen 2 kids tablet

Price: **£99.99 / (approx. $122.60)**
www.pebble-gear.com

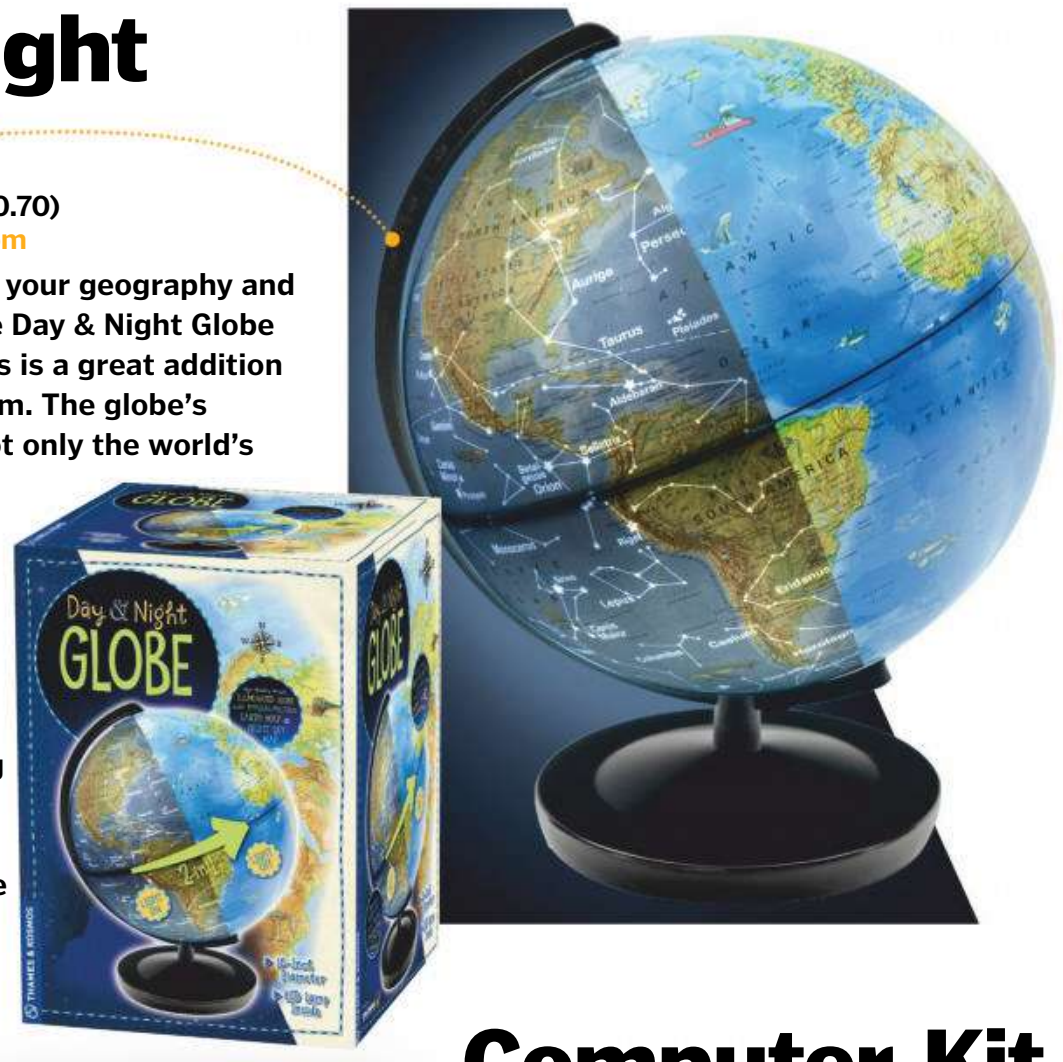
Keeping the youngest children in the family entertained while learning can be a difficult task. Products such as the *Frozen 2* kids tablet by Pebble Gear offer a great way to allow children to freely use some of the 500 games, educational apps and exclusive e-books while maintaining a level of fun. Each tablet is equipped with full parental control features and a polarising filter to help protect your children's eyes as they play and read.

© Pebble Gear

Day & Night Globe

Price: **$49.95 (approx. £40.70)**
www.thamesandkosmos.com

If you're looking to boost your geography and astronomy skills then the Day & Night Globe from Thames and Kosmos is a great addition to your at-home classroom. The globe's detailed design shows not only the world's countries and their borders but also mountain ranges, rivers and more. Flipping the globe's switch, this educational tool illuminates to reveal the stars overhead, depicting some of the most important constellations and stars that we can see from Earth.



© Thames & Kosmos, LLC

Computer Kit

Price: **£59.99 (approx. $73.60)**
www.kano.me

Venture into the world of computer programming with the Kano Computer Kit. This beginner-level kit opens the doors to understanding how computers work and the potential of coding. The kit is targeted at younger users, and alongside the Kano app uses easy-to-follow drag-and-drop code boxes to create images and even games. This is a great tool for any budding computer programmer and offers a community for online coding creators to share their hard work.

© Kano

© Thames & Kosmos, LLC

Happy Atoms Complete Set

Price: **$159.95 (approx. £130.40)**
www.thamesandkosmos.com

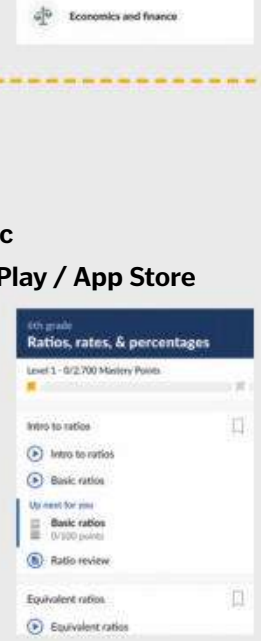
Visualising the atoms that make up the universe and everything within can be challenging. However, the Happy Atoms Complete Set from Thames and Kosmos is a great tool for understanding the world of molecules. Complete with magnetically connecting atom models, this science kit allows students to build a vast number of molecules from 16 periodic table elements. Once constructed, using the companion app models can be scanned and recognised to reveal a whole host of information about the properties of the molecules. The free app is also filled with guided quests to explore the world of molecules and tracks your progress to improve your knowledge of chemistry.

APPS & TOOLS

Simple Flashcards Plus

Developer: **RandomAppsInc**
Price: **Free / Google Play / App Store**

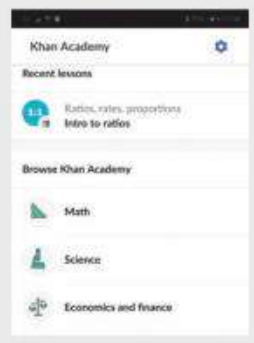
Flashcards are a great way to revise for an upcoming exam. This easy-to-use app boats millions of flashcards covering a wide range of topics.


Science Biology
Flashcard 1 of 42
What are cells
Cells are the basic building blocks of all animal and plant cell.
Flashcard 2 of 42
What are inside cells
Inside cells are various structures that are specialist to carry out a particular function
Flashcard 3 of 42
Cytoplasm
This is a jelly-like substance in which chemical reaction happens

Khan Academy

Developer: **Khan Academy**
Price: **Free / Google Play / App Store**

Jam-packed with practice exams, videos and articles, this app is a great resource for learning at home and for brushing up on your school subjects.



Quizlet

Developer: **Quizlet Inc**
Price: **Free / Google Play / App Store**

Quizlet is a great way to put your knowledge to the test with timed exams and to enhance your study with both written and video material.

Forest

Developer: **Seekrtech**
Price: **Free / Google Play / App Store**

One of the biggest challenges is staying focused on work. This simple app helps to stop you scrolling through your phone in order to grow virtual trees.

COGNITIVE RESPONSE
SPATIAL AWARENESS
LOGICAL-MATHEMATICAL
VERBAL REASONING
PEAR
HEAR
__AK
_EAR
___N

HOW TO THINK YOURSELF SMART

HOW IT WORKS EXPLORES THE POSSIBILITY OF TAKING YOUR IQ INTO YOUR OWN HANDS AND IMPROVING IT

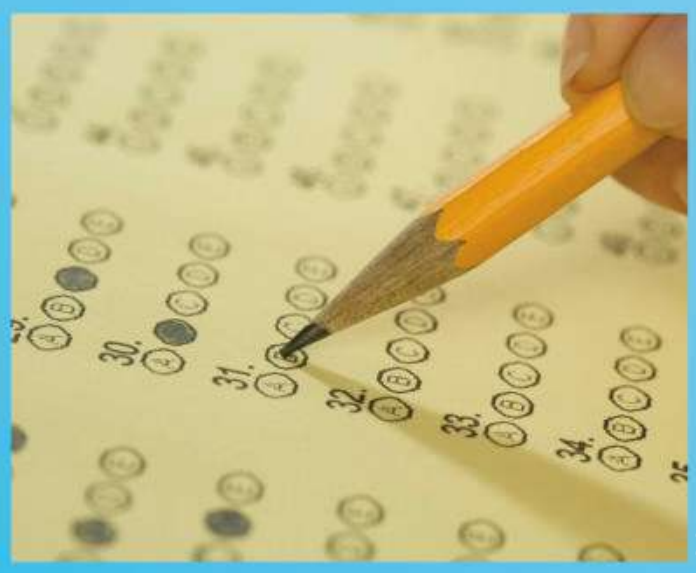
Words by **Scott Dutfield**

Staring down at the Sunday newspaper crossword, unable to work out nine down, you might be left questioning your intelligence and wondering if there's a way to sharpen your know-how. In recent years digital stores have been flooded with a host of different 'brain-training' apps all promising to help us think ourselves smart, but is that really possible?

Firstly, what exactly is intelligence? Is it something that we solely obtain from school, through our years of life experience, or perhaps a combination of the two? The concept of human intelligence is one that has been debated and researched for more than a century, with no clear answers.

However, what scientists have managed to agree upon is that it can be divided into two categories. The first is known as crystalline or crystallised intelligence. This refers to the intelligence that you might find useful in a pub quiz and centres on an acquired knowledge of the world. The second type, fluid intelligence, is the built-in smarts to problem solve and make decisions. Fluid intelligence is what is measured when taking an intelligence quotient (IQ) test.

So can we think ourselves smart? Cognitive training involves activities and tasks that are designed to help improve our intelligence or stall the inevitable decline of cognitive functions as we age. Brain-training exercises are delivered as repetitive tasks that measure



© Getty

IQ scores are calculated by comparing one person's performance on the test to others of the same age

certain cognitive functions, typically assessing what is known as 'working memory'. This is where you can retain information while at the same time completing another task without losing that information. When it comes to brain training, such tasks are a way to improve your working memory, which in turn has been found to improve your fluid intelligence. The idea is that over a set amount of time – for example five 30-minute sessions of training a week for four weeks – repeating these tasks might help you 'think yourself smart'. By gradually improving your test score, much like lifting weights at the gym, these exercises are designed to pump up your brain.

One such breakthrough in these tests appeared in 2008 from neurobiologists Susanne Jaeggi and Martin Buschkuehl, who published a training exercise called the dual n-back task. The basis of the test centres around participants listening to a flow of letters and assessing whether or not the letter matched one previously spoken, while they simultaneously watch a grid of boxes and note when a box appears in the same position as a previous one. Yes, it's just as mentally taxing as it sounds. It was believed that the dual n-back task showed dramatic improvements in peoples' fluid intelligence scores over time, showcasing that what was once thought to be built-in intelligence could potentially be upgraded using these types of tasks. Although Jaeggi and Buschkuehl's dual n-back task was one of the first intensive studies into improving fluid intelligence, 'brain-training' games and apps have been no stranger to the commercial market – one of the most popular being *Dr Kawashima's Brain Training* for the Nintendo DS released back in 2005. However, there are still debates about the real-world applications of brain training, with some arguing that the improvements are limited to the task itself and not applied to everyday life.

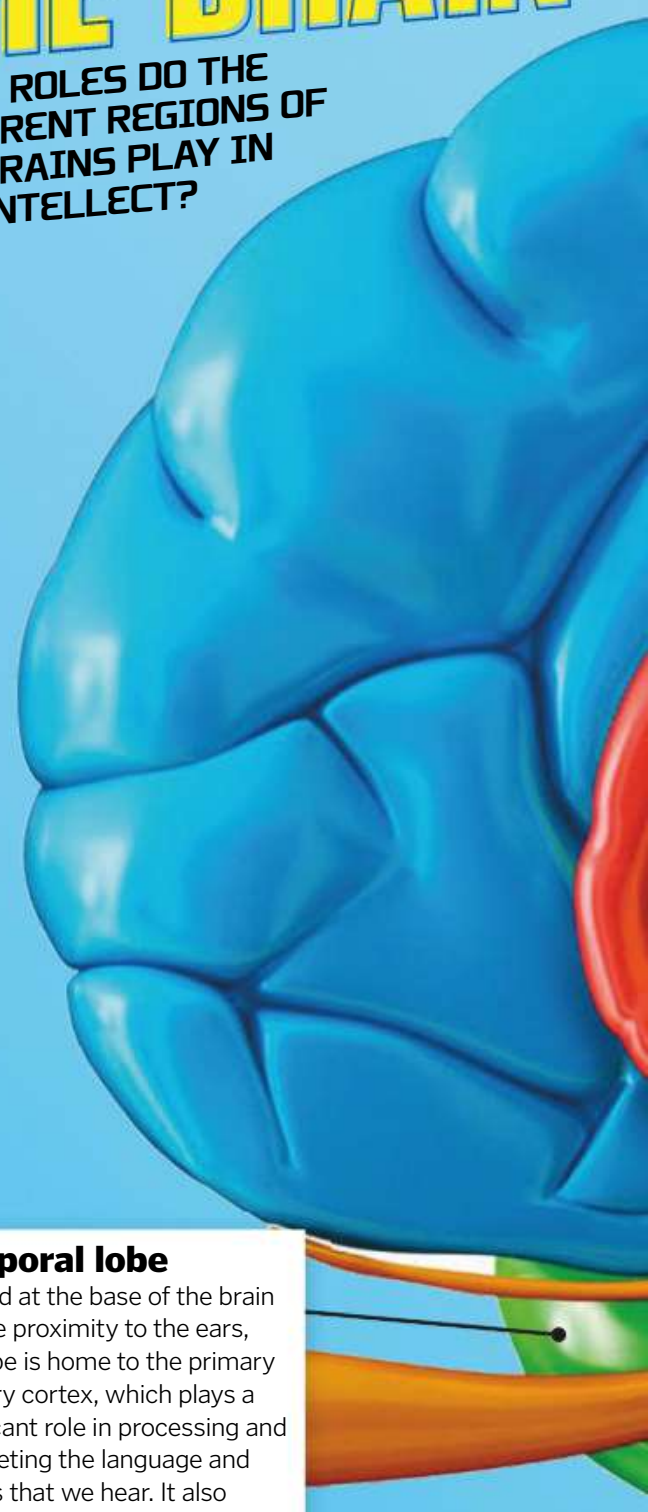
THE PROBLEM WITH IQ

Defining intelligence has been a controversial subject within the science community, with many attempting to provide the best possible explanation of how to label the way our brains work. Some even question the legitimacy of the existing standardised testing of intelligence, IQ.

One rather colourful theory was proposed by Harvard professor Dr Howard Gardner back in 1983, whereby he outlined eight different types of intelligence and retains the view that IQ testing is too limited. When applied to the way children are taught in schools, his theory suggests focusing on these intelligence types for effective learning.

INSIDE THE BRAIN

WHAT ROLES DO THE DIFFERENT REGIONS OF OUR BRAINS PLAY IN OUR INTELLECT?



Temporal lobe

Located at the base of the brain in close proximity to the ears, this lobe is home to the primary auditory cortex, which plays a significant role in processing and interpreting the language and sounds that we hear. It also contains structures that are involved with the formation of long-term memories.

IS BIGGER BETTER?

Well, if Albert Einstein's brain is anything to go by, then yes, bigger is better. A postmortem study of the brain of the extraordinary physicist revealed that his parietal lobes were 15 per cent larger than that of the average brain. As only one of the many explanations for Einstein's academic aptitudes, having a bigger brain might affect your intelligence, but some science suggests it's not by much. In a 2018 study led by the University of Pennsylvania, researchers found that out of 13,600 people, those with larger brains did perform slightly better on tests of cognition. Researchers explained that having an additional 100 cubic centimetres of brain tissue would increase the schooling age of a person by less than five months, implying it takes much more than just a big brain to be smart.

© Getty

A model of Albert Einstein's brain on display at the 2012 Wellcome Collection's exhibition Brains: The mind as matter

DID YOU KNOW? *The human brain is the largest of all vertebrates relative to body size*

Frontal lobe

The frontal lobe is involved in aspects of our intelligence that include motor function, problem-solving, personality development and language processing. Split into two halves, the left portion of the lobe controls the right side of the body and vice-versa.

Parietal lobe

Positioned at the top of the brain, the parietal lobe contains the somatosensory cortex, which is responsible for interpreting sensory information such as pain, pressure and touch. Sensory information from all around the body is processed in this part of the brain.

© Getty

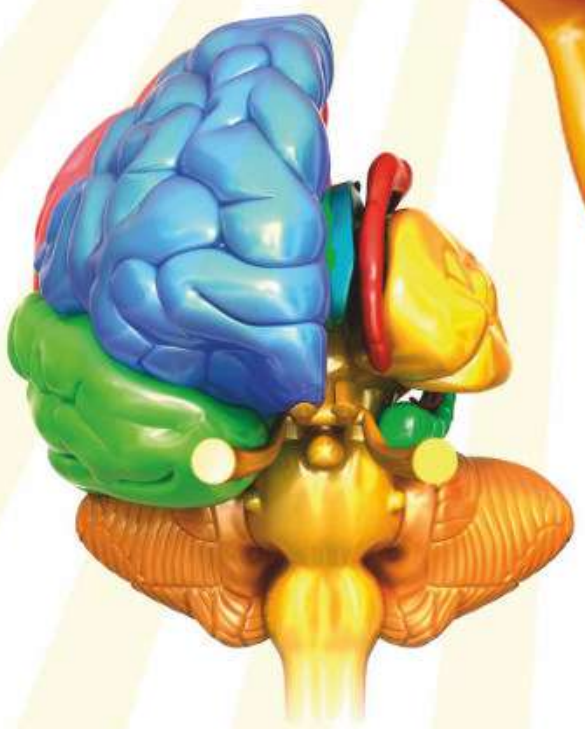
Scientists can use cases where regions of the brain have been damaged to assess their function after monitoring the effects on the patient

Occipital lobe

This area of the brain is home to our visual cortex, a region whereby visual information is received, interpreted and processed. Located at the back of the brain, the visual cortex stores that visual information and links mental images to different memories.

Cerebellum

Sitting at the base of the skull, this tennis-ball-sized region of the brain plays a large part in our motor control, movement and balance. Only occupying around ten per cent of the brain's overall volume, it houses over 50 per cent of the brain's total neurons. This high concentration of neurons has led scientists to believe it plays a role in higher level cognitive abilities and general intelligence along with its known sensory-motor function.



Intelligence by numbers

7 years old
Crows are as intelligent as some children

500 milliseconds
It takes around half a second to process sensory information

25
Your short-term memory peaks in your mid-twenties

135+
Only one per cent of people have a high IQ score

50 to 80%
Genetics accounts for the majority of our cognitive ability

538
A variety of genes contribute to your intelligence

1,274 cubic centimetres
The volume of the average male brain is nearly four times that of a canned drink

10 AT-HOME TIPS TO BOOST YOUR BRAIN

1 EAT 'BRAIN FOOD'

What we eat can have a massive effect on how well our brains perform. Foods such as blueberries, tomatoes, eggs and broccoli have all been linked to improving our cognitive functions. However, sources of omega-3 fat-rich foods, like salmon or flaxseed, have been at the forefront of brain-boosting foods for some years. Their high essential fatty acid levels are thought to promote healthier brain cells and are used in the construction of cell membranes. Also, low levels of a fatty acid called docosahexaenoic acid, found in oily fish and algae, have been linked to the increased risk of developing Alzheimer's disease. However, what powers our brains on a day-to-day basis is a form of sugar called glucose, which is released into the bloodstream after the stomach breaks down carbohydrate-rich foods.

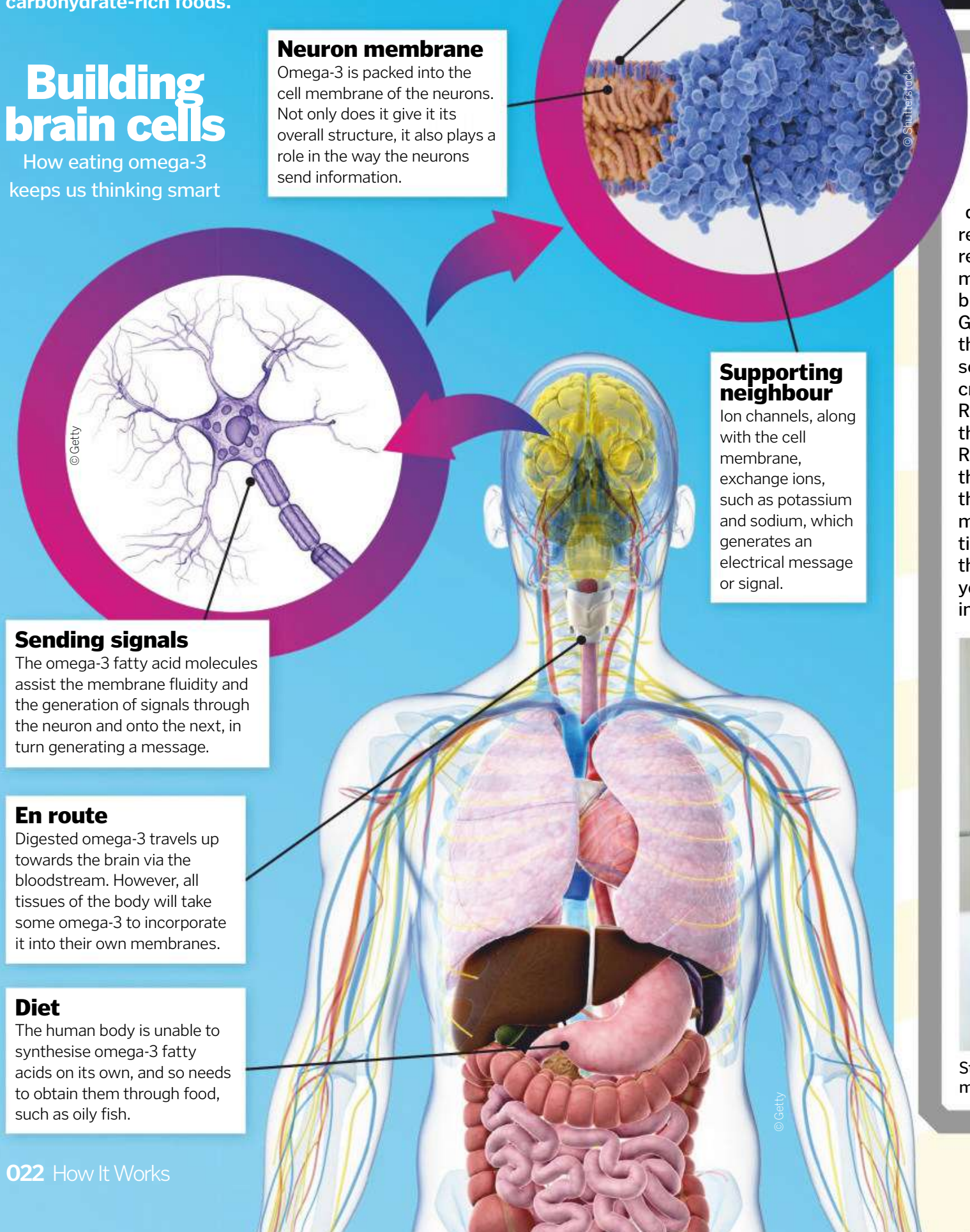
© Getty

Waterproof
The head of the omega-3 is hydrophobic, which means it prevents any adjacent fluid and ions from penetrating the cell membrane and generating a false signal.

Oily fish, including salmon, might be brain food you need to keep your brain healthy

Building brain cells

How eating omega-3 keeps us thinking smart



Neuron membrane
Omega-3 is packed into the cell membrane of the neurons. Not only does it give it its overall structure, it also plays a role in the way the neurons send information.

© Shutterstock

Supporting neighbour
Ion channels, along with the cell membrane, exchange ions, such as potassium and sodium, which generates an electrical message or signal.

© Getty

Sending signals
The omega-3 fatty acid molecules assist the membrane fluidity and the generation of signals through the neuron and onto the next, in turn generating a message.

En route
Digested omega-3 travels up towards the brain via the bloodstream. However, all tissues of the body will take some omega-3 to incorporate it into their own membranes.

Diet
The human body is unable to synthesise omega-3 fatty acids on its own, and so needs to obtain them through food, such as oily fish.

© Getty

2 LET YOURSELF DAYDREAM

It might seem counterintuitive that drifting off into a daydream would be related to intellectual ability. However, research has shown that letting your mind wander could be a sign of a high brain capacity. A 2017 study from the Georgia Institute of Technology found that those that frequently daydream scored higher on intellectual and creative tests than those who didn't. Researchers also scanned the brains of the participants using Magnetic Resonance Imaging (MRI) to evaluate their brain efficiency or capacity to think and found that daydreamers had more efficient brain systems. The next time you find yourself aimlessly gazing through a window, don't fight it and let your mind wander – it could be helpful in the future.

© Getty

Staring out the window and letting your mind wander might be good for you

3 BELIEVE YOU CAN AND YOU WILL

Self-belief is a great way to not only boost your confidence but also improve your smarts, a study has shown. When told it was possible to get smarter, it was found that students retained 85 per cent of what they had been taught in class. However, the second group of students were informed it was not possible, resulting in only 54 per cent of them retaining the information. It's thought that belief plays a role in the ease of brain neurons to cooperate.

4 STAY SOCIAL

In a time where face-to-face social interaction is at its lowest, it's important to remain social, not only for fun, but for your brain. Whether it's having a household games night or catching up with friends on a video chat, being social has been shown to improve and help preserve memory functions. Conducted between 1998 and 2004, subjects who were more 'socially integrated' showed higher scores on memory tests conducted every two years.

5 PRACTISE MINDFULNESS

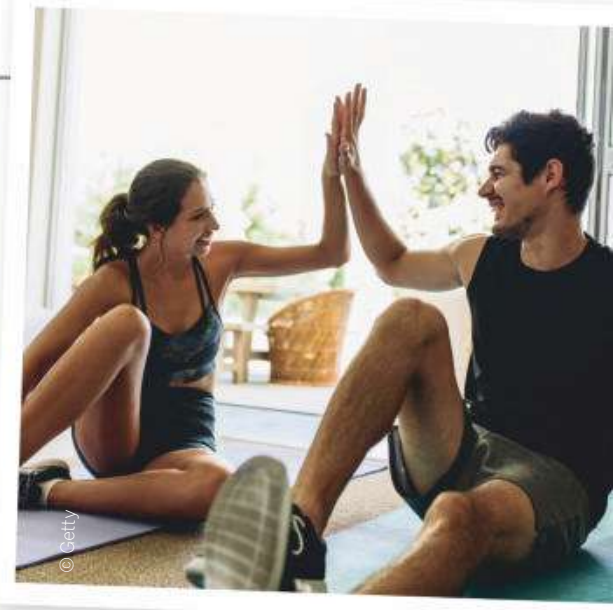
Our ability to make the right decisions is tied to our fluid intelligence and how well we can rationally consider information and make the right choices. Mindfulness, the act of paying attention to the present moment and understanding ourselves, has been found to improve mental health, but also help to better decision-making. Researchers have shown that a brief period of mindfulness, as little as 15 minutes per day, resulted in people making more rational decisions based on available information in the present moment, leading to positive outcomes.

© Getty

Taking a moment to reflect might help you make the right decision

6 STAY ACTIVE

Keeping up with regular exercise can keep your mind sharp as well as helping you stay fit. Studies have found that those that regularly exercise have bigger thinking and memory regions of their brains. Regular exercise has also been found to reduce the body's level of insulin resistance, stress and inflammation, along with promoting the release of chemicals that promote the growth of new blood vessels in the brain. However, one of the most immediate ways exercise can help the brain is by reducing stress. This is achieved by regulating your body's stress hormone, called cortisol. High levels of cortisol in the body have been found to negatively impact the way we think and our memory.



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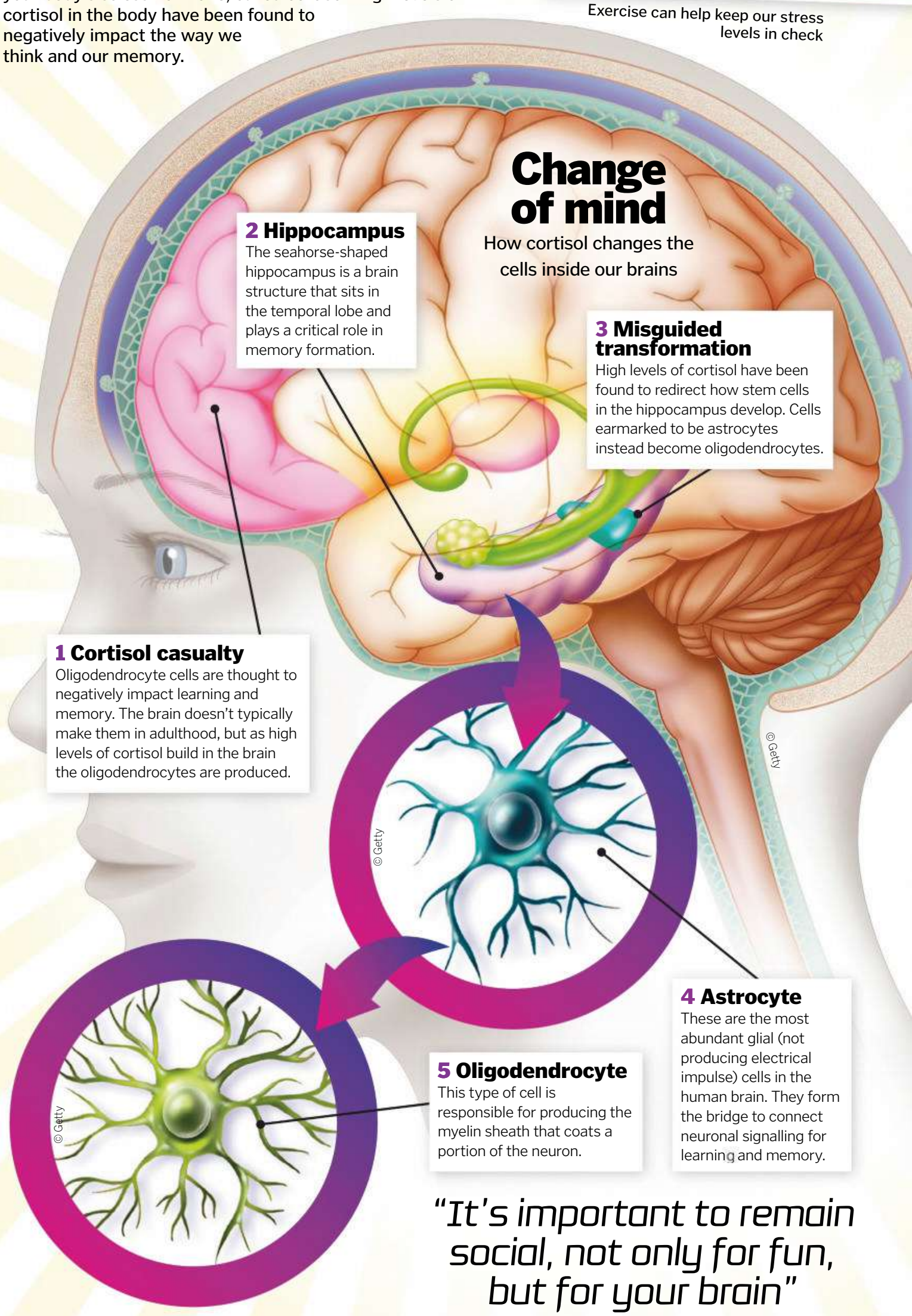
Exercise can help keep our stress levels in check


Change of mind
How cortisol changes the cells inside our brains
1 Cortisol casualty
Oligodendrocyte cells are thought to negatively impact learning and memory. The brain doesn't typically make them in adulthood, but as high levels of cortisol build in the brain the oligodendrocytes are produced.
2 Hippocampus
The seahorse-shaped hippocampus is a brain structure that sits in the temporal lobe and plays a critical role in memory formation.
3 Misguided transformation
High levels of cortisol have been found to redirect how stem cells in the hippocampus develop. Cells earmarked to be astrocytes instead become oligodendrocytes.
4 Astrocyte
These are the most abundant glial (not producing electrical impulse) cells in the human brain. They form the bridge to connect neuronal signalling for learning and memory.
5 Oligodendrocyte
This type of cell is responsible for producing the myelin sheath that coats a portion of the neuron.
© Getty

"It's important to remain social, not only for fun, but for your brain"

7 PLAY SOME VIDEO GAMES

It was commonly believed that playing video games did the opposite of improving the way our brains work. However, plugging in your console and spending the afternoon in a virtual world might have some cognitive benefits. Researchers have found that playing action-oriented video games increases our ability to analyse situations and make quick decisions, along with improving our ability to perceive shapes and colour.

8 GET LOST IN FICTION

Burying your head in a textbook will help grow your crystalline intelligence and gain knowledge. However, poking your nose into a work of fiction is believed to improve your emotional intelligence. Immersing yourself in books filled with detail, allusion and metaphors activates the same regions of the brain that would be simulated in real-life situations. Reading moral dilemmas in fiction, for example, is known to exercise the brain and increase our capacity for empathy.

9 LEARN TO PLAY AN INSTRUMENT

It might be time to dust off that guitar that's tucked away in the attic or pick up that recorder for the first time since school to help improve your cognitive function. Other than acquiring a new skill, learning to play an instrument has been found to engage almost all parts of the brain and improves language and cognitive skills.

© Getty

© Getty

Your brain might thank you for a daily cup of green tea

10 DRINK GREEN TEA

How much difference can a cup of green tea make to the brain? Well, a long-term study published in the science journal *Experimental Gerontology* has found that a chemical compound found in green tea called catechin might be able to reduce cerebral atrophy – loss of brain cells – and function. The study used mouse subjects over 12 months and discovered that green tea catechin effectively suppressed atrophy, along with improving brain function in the brains of older mice subjects.

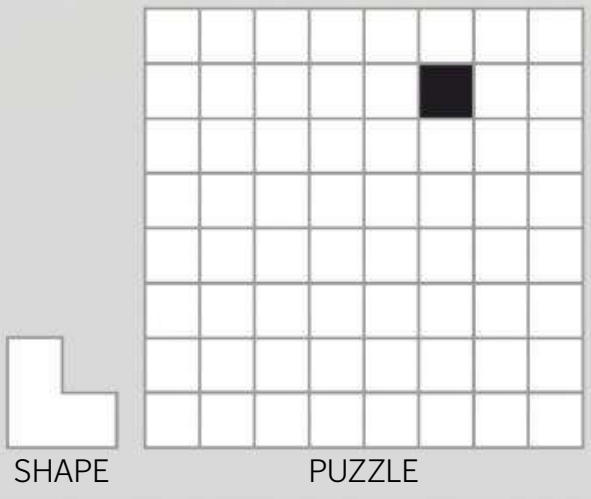
TEST YOUR SMARTS

HERE ARE SOME FUN PUZZLES TO KEEP YOUR BRAIN ACTIVE, BUT CAN YOU COMPLETE THEM ALL?

An aspect of our intelligence and cognitive function is our willingness to persist with a task despite initially finding it difficult. This is what is known as cognitive engagement, and is defined as the effort which students are willing to invest in working on a task.

Q1 CAN YOU FILL THE JIGSAW?

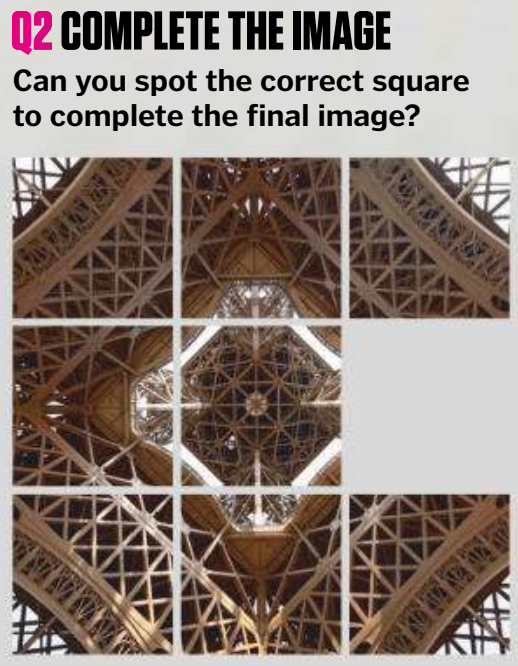
Draw enough of the jigsaw shape – which is equal to three squares – onto the grid to completely fill it.



SHAPE PUZZLE

Q2 COMPLETE THE IMAGE

Can you spot the correct square to complete the final image?



A B C

Q3 WHAT NUMBER COMES NEXT IN THE SEQUENCE?

3, 6, 18, 72 .....

4, 10, 28, 82, 244 .....

20, 19, 17, 14, 10 .....

9, 11, 20, 31, 51 .....

Q4 CAN YOU MATCH THE SYNONYMS?

A DETRIMENTAL	G TALKATIVE
B CONNECT	H SCATTER
C DISPERSE	I HARMFUL
D OFTEN	J PLENTIFUL
E ABUNDANT	K JOIN
F LOQUACIOUS	L FREQUENT

THE MYTH ABOUT MODAFINIL, THE 'SMART DRUG'

Whether you're cramming for a university exam or working late on tomorrow's big presentation, popping a 'smart pill' might sound like the perfect solution to get you through. Back in 2014 a drug called modafinil hit the newsstands, being branded as a 'smart drug' to improve brain performance. Typically used to treat patients with narcolepsy, the pill promotes 'wakefulness' in those that take it. However, when it comes to boosting our brain power, studies have shown that modafinil did not improve cognitive function, but instead slowed study participants' responses when compared to those given a placebo pill.

© Alamy

A study of 64 healthy people taking modafinil found their responses were slowed when asked to complete a sentence

Q&A BRAIN-TRAINING EXPLAINED

© XXXXXXX

Dr Claudia von Bastian, a lecturer in psychology at the University of Sheffield, explains some of the evidence behind brain training and how it might not be for everyone

How does our intelligence change as we age?
The developmental evidence and life span studies show that fluid intelligence and crystalline intelligence both grow and increase and become better. Crystalline intelligence more or less grows all life long, whereas in fluid intelligence it grows and grows and grows up to around the 20s, and then it starts to flatten. Then it goes down in older age and you have a decreased fluid intelligence compared to earlier in life. You can think of it as like an inverted 'U' curve shape, but not an extreme 'U'. It's growing steeper in early life until the frontal lobes are fully developed in the early 20s, and then it flattens, and then it gradually decreases. In crystalline intelligence, it rises and rises and then maybe in midlife it reaches a plateau, but then it very slightly increases further or at least stabilises, but it doesn't decrease.

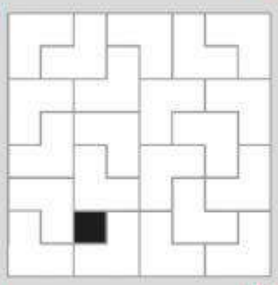
Can brain training help flatten that curve as we age?
That would be the idea behind brain training, that you would be able to counteract that decline, especially in ageing. However, the evidence for that is very, very weak. It depends a little bit on what your goal is. If you want to really flatten the curve so that you don't have that decline in a meaningful way, that is what we don't have any evidence for. What you can do is just practise the tasks that are assessed extensively, and then you will show better test scores, but it doesn't mean anything if you don't seek to generalise it to other contexts. I would say at the moment the evidence isn't there that this really works.

Is there a particular age where brain training would be most effective?
I know of no convincing evidence, but I would say so. Intuitively you would think that it would help most when you are in development or already on the decline, so you would think it helps most for older adults, or if you're still developing, so it might help most for young children, but there is no convincing evidence that actually confirms that, even though it would be plausible.

Are brain-training tasks a 'one-size-fits-all' solution?
That would be ideal, right? But that's exactly the problem when people try to find this one-size-fits-all kind of approach, this kind of quick-fix solution that could make people miraculously smarter, but that doesn't seem to work. For example, brain training that tries to make your kids smarter by practising working memory. It might be better to actually practise maths if you want to improve your maths skills. Or if you want to improve some certain aspects of your daily life, it might be better to actually practise those aspects rather than trying to do this brain training as a quick-fix solution. I think, if anything, you would need more tailored interventions than broader interventions.

ANSWERS

Q1



Q2 C

Q3 **360** (x2, x3, x4, x5)
5 (-1, -2, -3, -4, -5)
730 (+6, +18, +54, +162, +486) (x3)
82 (each number is the sum of the preceding 2 numbers, 9+11=20)

Q4 A&L, C&H, E&J, F&G, B&K, D&L

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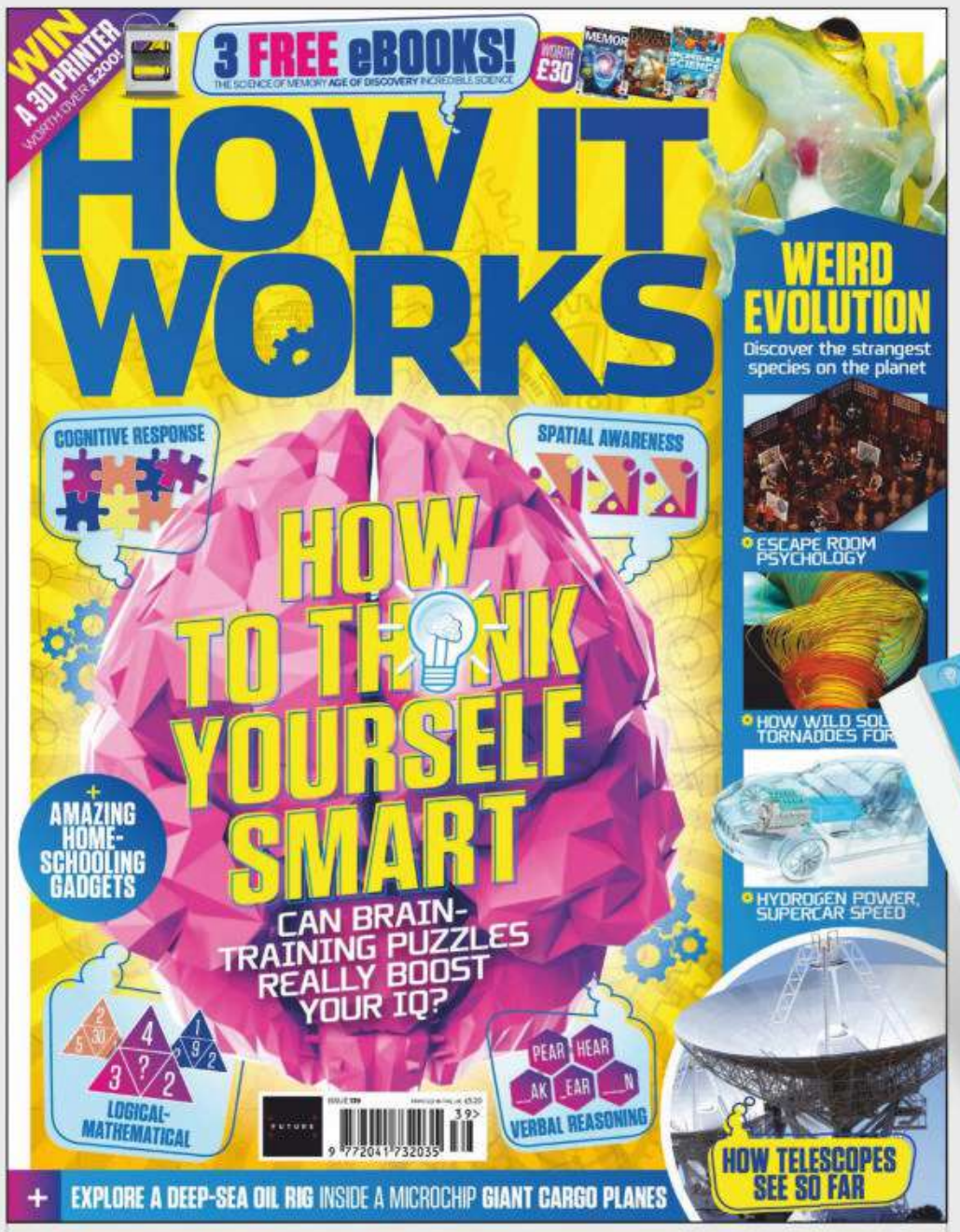
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10 EVOLUTIONARY WEIRDOS

These animals have evolved unique appearances, impressive superpowers and some strange habits

Words by **Ailsa Harvey**

There are roughly 150 different types of glass frog

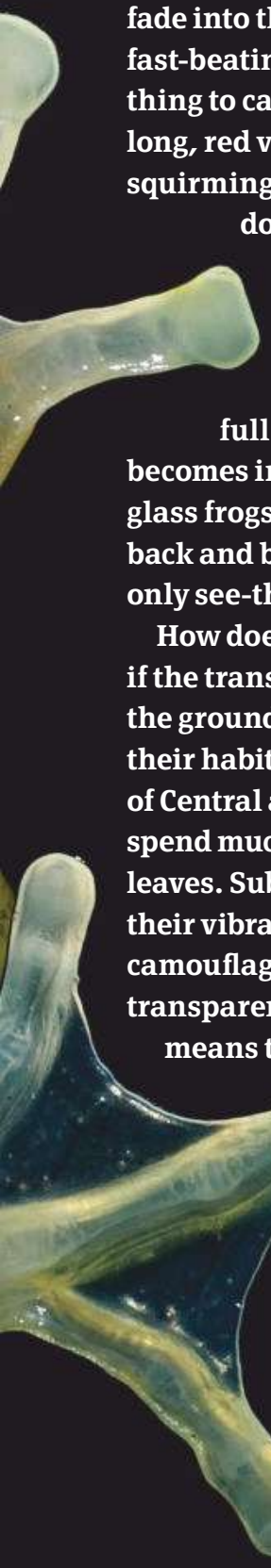
© Getty

Invisible frog

Being both vital for life and the most delicate parts of our bodies, it's no surprise that we don't often see our internal organs, or those of other animals. Most bodies are built with them hidden inside multiple protective layers of skin, tissue and bone. But what if these layers were see-through?

Looking at a glass frog from above, you may not see anything out of the ordinary compared to other frog species, being the same shape and that classic green colour we often associate with them. But if you were to look at its underbelly, its shape would suddenly fade into the background. A tiny, fast-beating heart would be the first thing to catch your eye, along with a long, red vein. Next to this a section of squirming intestines work to break down food. These amphibians have evolved to have an extremely thin, translucent skin. While this puts its entire internal anatomy on full display, its overall shape becomes invisible to predators. Some glass frogs have this skin on both the back and belly, but the majority are only see-through from below.

How does the frog have any advantage if the transparent area is always facing the ground? This all comes down to their habitat. Living in the rainforests of Central and South America, they spend much of their time perched on leaves. Submerged in luscious greenery, their vibrant topcoats are ideal for camouflage. Meanwhile, their transparent base means that while they sit high on a tree's leaf, with light shining from above, their silhouette is much less visible from below.



Living in a fig

The life's work of a fig wasp ensures the survival of both insect and plant

1 Making an entrance
Covered in pollen, the female fig wasp burrows into the fig's opening. In the process its wings are torn off.

2 Egg laying
Once inside, the wasp lays her eggs in her new home. She must spend the last day of her life digging tunnels through the fig flesh.

3 Protected young
The flowers that have unborn wasps laid inside close up in a protective bud, while other flowers are pollinated by the wasps to make seeds.

4 Mass hatching
When grown, the wasps begin to emerge from their pods. Male wasps are born first, exploring the inside of the fig. They mate with the females before they are released.

5 Flowering fig
The fig and wasp have evolved to synchronise their actions. Pollen is produced by the fig before the female wasps hatch so that they can pick it up.

6 Male fig wasps
The males' lives are far less glamorous. Without wings, the only job left is to help dig escape tunnels before their short lives are over.

7 On the move
Pregnant and equipped with pollen, the female wasps use their parents' and mates' previously dug exits. They take to the sky to search for a new fig.

8 Fig finding
These tiny wasps can fly ten kilometres, and on some occasions 160, to find their new home. It's here that their life will end, but also give new life for many more wasps and figs alike.

©Getty

Wasp-fig relationship

Unlikely relationships are often formed in the wild, and those that survive have usually evolved to find mutual benefits for the two species. One case of this is the fig wasp, which has found an unusual home inside the fig fruit.

When female wasps are released into the world, they have their senses set on one thing. Instinctively searching for a fig tree, they begin digging their way into the soft, sweet flower when they find one. Here the female wasps are protected and out of sight, and are able to lay their eggs. The wasp will not see the outside world ever again. Instead they dedicate the end of their lives to their unborn young, building tunnels to give them an escape route. For the mother, entering the fig has broken her wings, and in this home she will die just 24 hours after laying the eggs.

"The female wasps are protected and out of sight"

It might not sound like the perfect life, confined to a fig and digging to death, but this method has kept this wasp species alive for over 60 million years. Figs have these insects to thank for their continued existence, as their movement from one fig to another spreads their pollen.

Source: Wik/Alandmanson

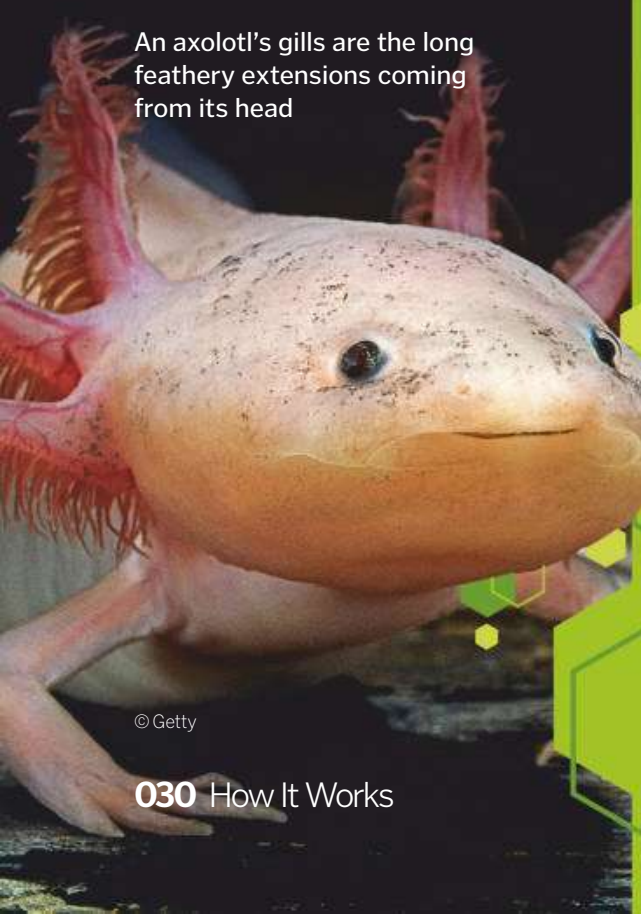
Some fig wasps have developed long extensions in order to lay eggs without entering the fig

Walking fish

3 **As this animal swims around like a gigantic tadpole, the first apparent quirk may be its protruding, spiky hairdo. But when it approaches the ground and four legs unexpectedly pull down from its side, it is clear that this is no ordinary fish. This is the axolotl, known as the 'Mexican walking fish'.**

Although they look like overdeveloped fish, they are actually amphibians. In some ways the axolotl has evolved to remain underdeveloped. Often amphibians begin their lives with gills, living in the water, but eventually grow to become land animals. This species keeps its ability to breathe underwater and also does not lose its gills.

In this reverse evolutionary process, called neoteny, the axolotl descended from terrestrial salamanders. Never leaving the water, they are found in the lakes of Xochimilco near Mexico City. Growing up to 30 centimetres in length, they feed on small insects, worms, molluscs and crustaceans. Historically, these grinning creatures were at the top of the food chain, but invasive fish species and pollution are now threatening their' survival.



An axolotl's gills are the long feathery extensions coming from its head

© Getty

Male seahorses are pregnant for between 10 and 25 days

© Getty

Pregnant males

4 To us – and most of the animals on the planet – it is the norm for females to carry babies and give birth. However, females take a break from this all-consuming job in the case of three animals. The seahorse, pipefish and sea dragon are all members of the Syngnathidae fish family and are all in the exclusive pregnant fathers group.

Seahorses are the only of the three to carry their young inside a full pouch. The other two, while carrying their offspring, have them attached on the outside of their bodies, supplying nutrients through the tissue.

Does this evolutionary change show any benefit to the species? Scientists believe that with the males taking on this role, the females can get straight back to creating further eggs, giving them to the male as soon as he has given birth. This helps the species' numbers increase for a higher chance of survival. Secondly, sharing the role of child carrying doesn't leave one temporarily drained of energy.

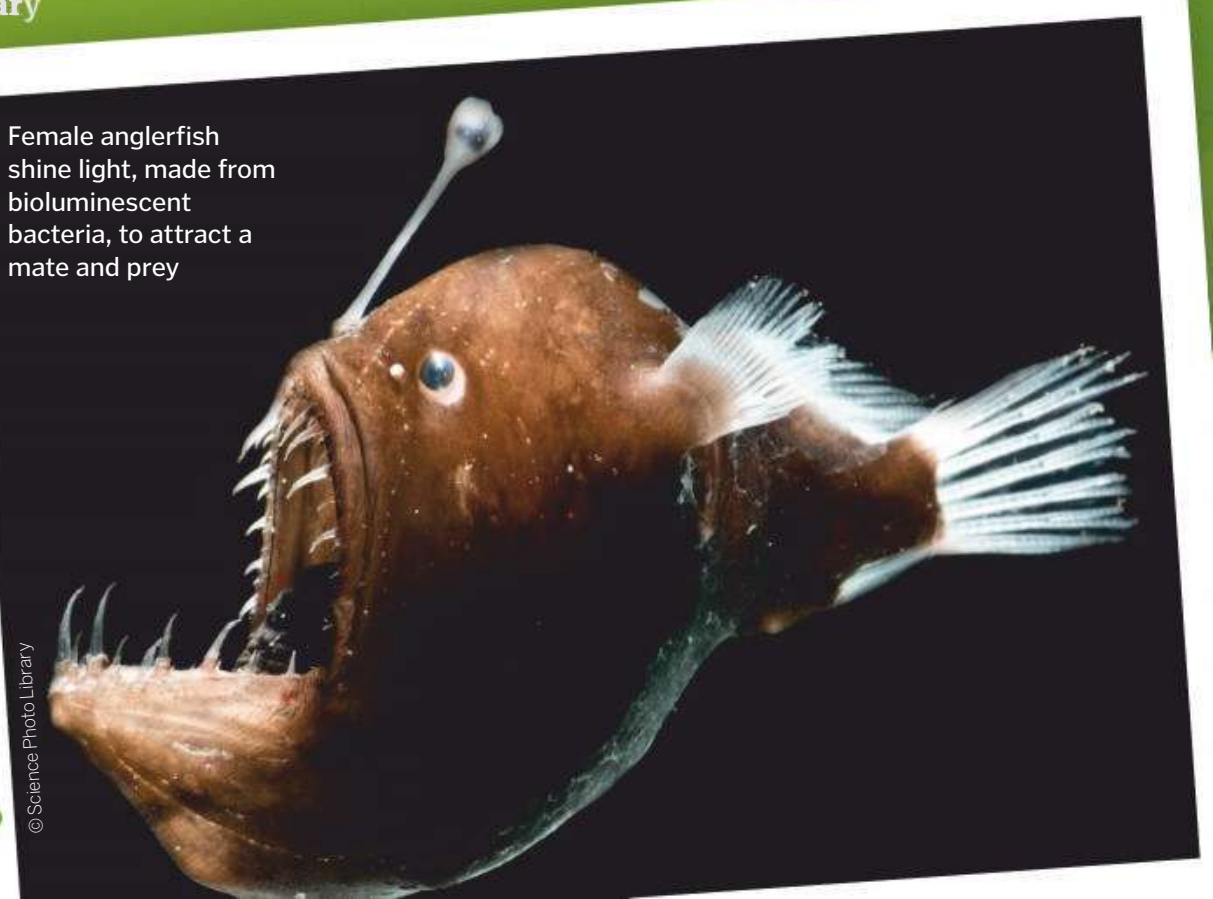
Parasitic mates

5 **The male and female anglerfish are so varied in appearance that you probably wouldn't put them together at first glance. In fact, with the female being up to 60-times longer and half a million times heavier than her male partner, it was originally thought that they were different species entirely.**

The most familiar image of the anglerfish is actually the female. Found lurking in the ocean's darkest depths, with their overhanging light rods illuminating their way and their terrifyingly large fangs, these fish of nightmares are evolutionary oddities in themselves.

But the arrival of the males makes everything even more peculiar. When mating, the male anglerfish acts like a parasite. Biting into the side of his chosen female, the tiny blood-sucker steals beneficial nutrients from her as his body fuses with hers. This is an easier way of life for the male. Not needing to swim or see, the male's eyes, fins and even some organs begin to deteriorate. He gets everything he requires for little effort, while his only responsibilities are to provide reproductive cells when the time is right.

This strange approach to reproduction has continued to be successful due to the smaller male's lesser needs.



Female anglerfish shine light, made from bioluminescent bacteria, to attract a mate and prey

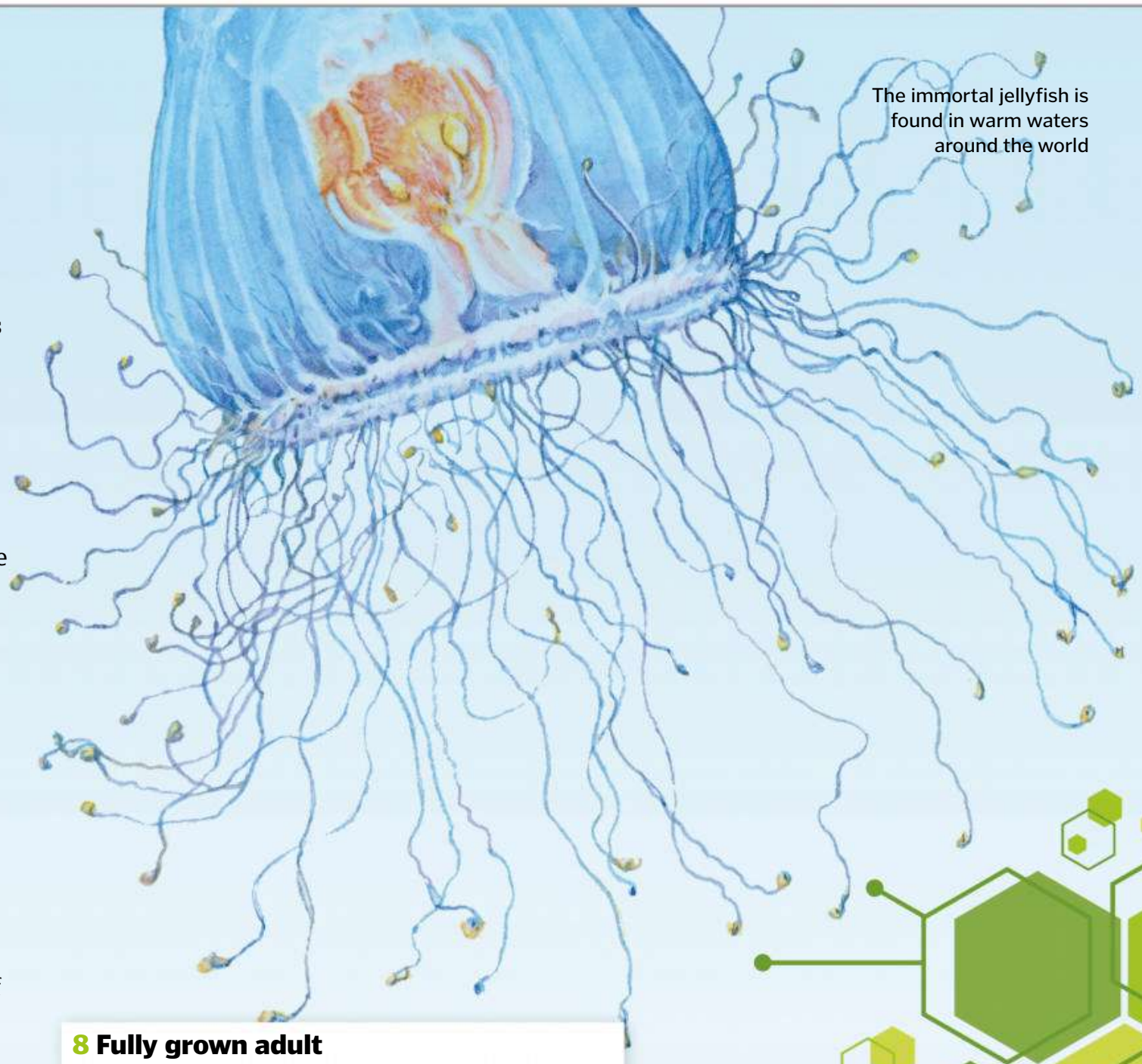
© Science Photo Library

Immortal jellies

Do you ever wish you could jump back in time to when you were younger and start life again? As life passes us by, our bodies are designed to grow, age and eventually die. However, not all species follow this cycle. Meet the immortal jellyfish, *Turritopsis dohrnii*.

Achieving what is merely a superhero fantasy for many of us, age doesn't kill these tiny, bell-shaped marvels. Instead of following just one life cycle, the jellyfish can ride the cycle continuously, or until they find themselves in the jaws of their fish predators. Reverting their bodies back to their younger state, they have multiple chances at life.

Super-powered doesn't necessarily mean super-sized. At their largest they are still less than five millimetres both in height and width. These jellyfish were first discovered in 1883 in the Mediterranean Sea, but only gained their new moniker of the immortal jellyfish in the mid-1990s. While being studied in a lab, the jellyfish skipped the fertilisation stage and regressed in maturity. It is thought that the immortal jellyfish might use this skill in cases of emergency, such as in the stressful situation of being contained in a small space.



The immortal jellyfish is found in warm waters around the world

The immortal cycle

The jellyfish reverses maturity to relive the cycle

1 Egg
The jellyfish's life begins when the female's egg is fertilised by a male.

2 Planula larva
When the eggs have developed into planula larvae, they are released into the ocean, beginning a brief free-swimming stage before settling on the sea floor.

3 Fixed planula
Attached to the floor via one end, the planula stops to develop some more jellyfish-like features. It starts to grow tentacles and a mouth.

4 Polyp
When attached to the hard surface, it begins to transform into a polyp. Sometimes remaining in this stage for several years, it is this cylindrical, pre-jellyfish stalk that adults can later revert back to.

5 Grown polyp
The polyp continuously splits its cells to produce numerous clones of itself. When doing this its height grows.

6 Baby jellyfish
Layers of the polyp split from the top of the cylinder, becoming mobile creatures that can travel the sea. These are baby jellyfish called ephyrae.

7 Juvenile
The young jellyfish gradually grows and matures. It begins to adopt the larger, smooth bell of the adult jellyfish.

8 Fully grown adult
With its complete umbrella-shaped bell and developed tentacles, the jellyfish has reached full maturity. At this point it has the option to relive most of the cycle by modifying its cells.

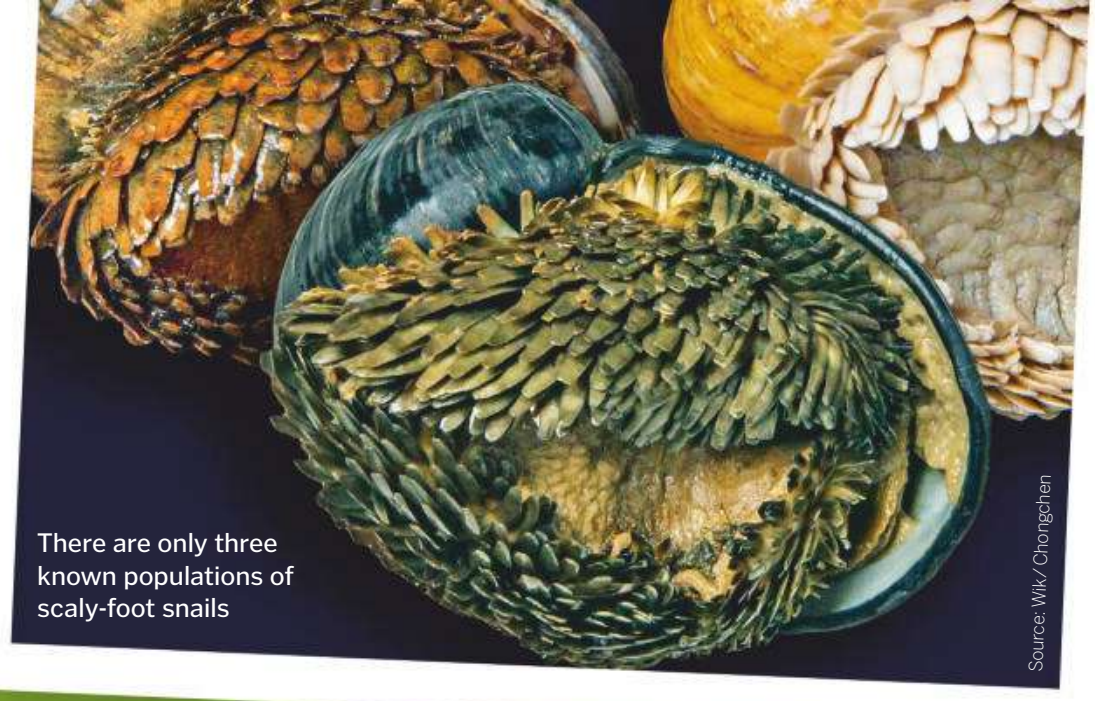
Self-freezing stone wētā

7 New Zealand's mountain stone weta is the world's largest freeze-tolerant insect. It is able to freeze 80 per cent of its body and return to life once thawed. Accustomed to life in the chilly mountains of the South Island, these cold-blooded creatures have ice-nucleating agents in their blood. This substance does the opposite of anti-freeze, promoting freezing rather than preventing it. Water in the body outside its cells is allowed to crystallise while the insect prevents ice crystallisation inside its cells.

During the coldest months, the stone weta can literally put a pause on its life. Able to thrive where no normal insect would, every year when temperatures drop below -10 degrees Celsius, it spends around five months inactive. In this state, biological functions are slowed down to reduce the body's needs so that the insect can remain alive for long periods.

At ten centimetres in length, the mountain stone weta is big for an insect

© Steve Trewick



There are only three known populations of scaly-foot snails

Source: Wiki/ Chongchen

Scaly-foot snails

8 Evolution sometimes involves a fight between species to become the most successful in a habitat. And what better way to fight for survival than to build your own armour? One sea snail species, the scaly-foot snail, lives thousands of metres underwater. Occupying hydrothermal areas of the Indian ocean, they protect themselves by building their very own iron shell. Living on a volcanically active sea floor, surrounding vents spurt boiling water. This release from below the ocean bed is also rich in chemicals and nutrients. In these volatile areas, there is often a high abundance of iron, which the snails are able to utilise and put to impressive use.

The shell is made of layers of different consistencies. The outer part of the armour is hard iron and will stop the claws of crabs and other predators, while underneath is a softer iron, softening any impact to the snail's squishy body beneath.

One dung beetle species can roll dung 1,141 times their own body weight

© Getty

Dung beetle astronomers

9 What is most precious to you? Chances are a pile of animal poo comes pretty low in your list. For a dung beetle this is right at the top, being used for food, a nest and more. Travelling several miles to find piles of it, they then roll it into manageable-sized balls, ready for transportation back to their home. These insects spend day and night travelling land, so how do they ensure they get their most prized possession back safely? The answer is in the stars.

Dung beetles have learned to follow the Milky Way as they travel at night. Looking up to the sky as they roll their ball, they use the stars' light to make sure they stay travelling in a straight line. The insects' eyesight isn't good enough to see individual stars, but can make out the Milky Way's bright stripe.

Brainless squirts

10 Sea squirts might look like plants of the ocean, but they are actually rather advanced animals. When fully grown, these potato-shaped organisms sit brainless and stationary at the bottom of the ocean. However, before this stage they had a much more active life.

Born looking similar to tadpoles with a backbone and muscular tail, the sea squirt is free to explore the ocean. The young sea squirt is tasked with finding a suitable place to live the rest of its life. It does this using its sucker located on its head. Once attached to the surface, whether that is the sea bed, bottom of a ship or back of a crab, the sea squirt no longer needs its brain. Fed automatically by the sea's nutrients as water streams through its gills, all the animal needs to do is release reproductive cells for the continuation of the species. In fact, shortly after finding the surface to spend the rest of its life on, the sea squirt eats its own brain and its tail disappears. Protecting themselves might sound difficult without a brain, but this comes as an automatic response. They react to touch by squirting water and waste products, deterring predators.

Some sea squirt species live in colonies

© Getty

Inside the sea squirt

It may have eaten its brain, but what other organs keep it alive?

© Illustration by Nicholas Forder

Opening siphon
This siphon brings water into the sea squirt. Hair-like structures inside the tube form a current to draw it in.

Huge filter
This area filters out waste products and excess water, while nutrients and some water remain to be digested.

Nerve cells
With no brain, a group of nerve cells allows the body to sense touch. This is crucial in triggering its squirt response.

Release siphon
Giving them their name, sea squirts tend to squirt water when they are under attack or need to release waste. Contracting their bodies forces water and waste out of this tube. It is possible for them to squirt out their entire digestive tract and then grow it back again.

Protective tunic
The animal has a thick protective layer to protect internal organs. It has evolved to need this layer as it spends the majority of life immobile and with limited defence.

Waste products
The products that haven't been used in the body are released into a large cavity. This cavity also holds the water and waste from the first filtering process.

Slither heart
The elongated heart contracts at one end, which spreads to the other side of the heart and then changes direction. This pumping system circulates blood around their bodies.

Stomach
Like in our stomach, the sea squirt uses enzymes to break down the filtered food.

Reproductive organs
Though they have both male and female reproductive organs, they can not reproduce by themselves. The eggs stay in the body waiting to be fertilised by another sea squirt.

AR ZONE! SCAN HERE

5 FACTS ABOUT ANIMALS ADAPTING TO CITY LIFE

1 Lizard toes
Anole lizards have adapted to navigate Puerto Rican cities by acquiring more lamellae – sticky structures – on the bottom of their feet. These allow them to run vertically up windows and face obstacles life in the city presents.

2 London's mosquitoes
Members of the same species can sometimes diverge into separate ones when isolated in diverse climates. Often vast oceans create these barriers – or, less often, a city transport system. The London Underground mosquito spends its days in the subway system and has adapted to feed on the public as they hop on and off trains. Unlike their closest relatives above ground, which mainly feed on birds, the underground mosquito has been separated in the system so long it has become its own distinct species, feeding only on commuters.

3 Pollution-proof fish
Crowded cities bring increased pollution. Polluted skies and water will impact most animals, but for one fish the battle to survive has led to it becoming more resistant to dirty water. The mummichog has modified 20 per cent of its genes to be able to live in some of the world's most polluted rivers.

4 Swallow wingspan
When it comes to obstacle dodging, a shorter wingspan helps a bird manoeuvre. This is shown in the case of cliff swallows. While they usually live in open spaces with no reason to perform quick turns, these swallows have begun living in populated cities. Demonstrating natural selection, the shorter winged birds had lower death rates from oncoming traffic and have developed into a more agile species for their new home.

5 Takeaway rodents
Mice living on the streets of New York can handle a much fattier diet than their rural relatives. Becoming frequent diners on leftover fast food, these mice have developed changes in their genes that allow them to metabolise fat better. This is a similar change to one humans experienced when the hunter-gatherer lifestyle ceased.

Multistorey life in the rainforest

The rainforest is a three-dimensional world, with multiple levels of wildlife up its towering trees

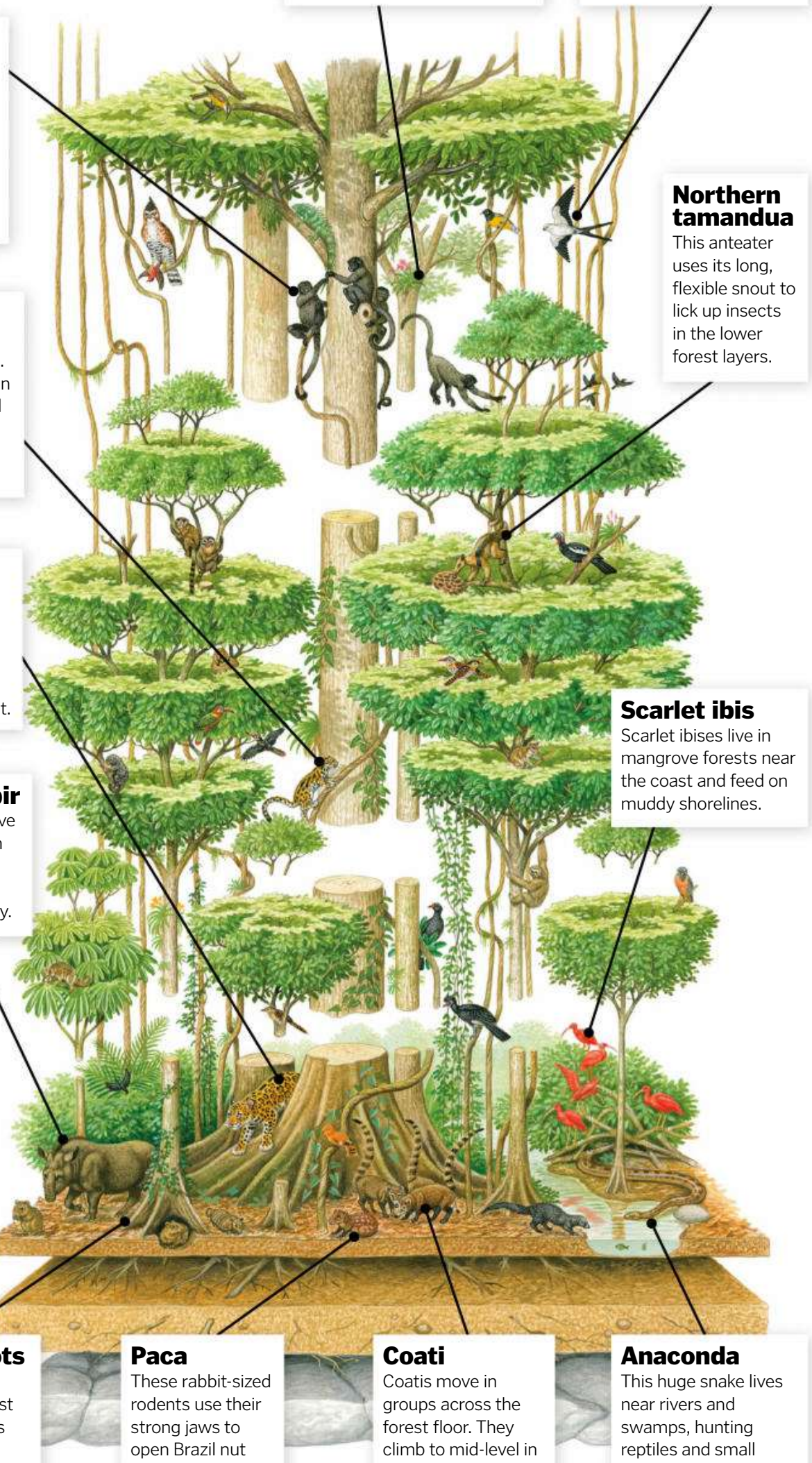
Tropical rainforests are incredibly rich in wildlife. They cover roughly six per cent of Earth's land, yet they are home to around half of all the known species of flora and fauna. In the year-round warm and wet conditions, plants can grow, flower and fruit nonstop. That allows trees to quickly reach great heights. In a typical rainforest the treetops overlap to form a continuous green layer called the canopy, about 45 metres above ground level. A few trees, called emergents, protrude and project well above this canopy – the tallest reaching some 70 metres high.

The dense canopy of leaves blocks most sunlight from reaching the ground, where it is shady, damp and dank. For a visitor expecting to see a jungle full of colourful birds and monkeys, the rainforest floor is disappointing. A few small mammals do scurry about here, feeding on fruit that's dropped from above, but they are mostly shy and secretive. Wild cats, like ocelots and jaguars, hunt them – mainly at night – but these are even more difficult to spot.

Life on the forest floor is mostly small and hidden. Dead animals, broken branches and even whole trees from above are the food for a myriad of insects, worms and fungi. Along with bacteria, these decomposers play a vital role, quickly breaking down the detritus and releasing minerals and nutrients back into the soil to nourish new life in a perpetual cycle.

Meet the low life

The lower storeys of the rainforest are leafy and shady, but jam-packed with hidden life



Epiphytic orchid
Thousands of species of orchid live as epiphytes – growing on the platform of a branch, but extracting nothing from the tree, unlike a parasite.

Swallow-tail kite
This agile bird of prey soars above the canopy searching for reptiles sunning on branches, then swoops in to snatch them.

Woolly monkey
These noisy monkeys travel by day in large troops through the middle canopy, and rarely venture to the ground.

Northern tamandua
This anteater uses its long, flexible snout to lick up insects in the lower forest layers.

Ocelot
Ocelots are medium-sized cats. They hunt mainly on the forest floor and spend the day well-hidden asleep in trees.

Jaguar
Jaguars are shy, solitary and rarely seen. They mainly hunt on the forest floor but can climb trees to hunt or rest.

Brazilian tapir
Tapirs are only active at night, foraging in swampy terrain. They hide in dense undergrowth by day.

Scarlet ibis
Scarlet ibises live in mangrove forests near the coast and feed on muddy shorelines.

Poison-arrow frog
Bright colours warn predators that these amphibians are deadly. Natives use the poison to tip their arrows.

Rainforest fungi
Rainforest fungi produce a spreading network of fine threads to decompose dead wood. These 'mushrooms' are their spore-producing fruiting bodies.

Buttress roots
Tree roots get little grip in thin rainforest soils, so many trees also have massive buttress roots to help prop them up.

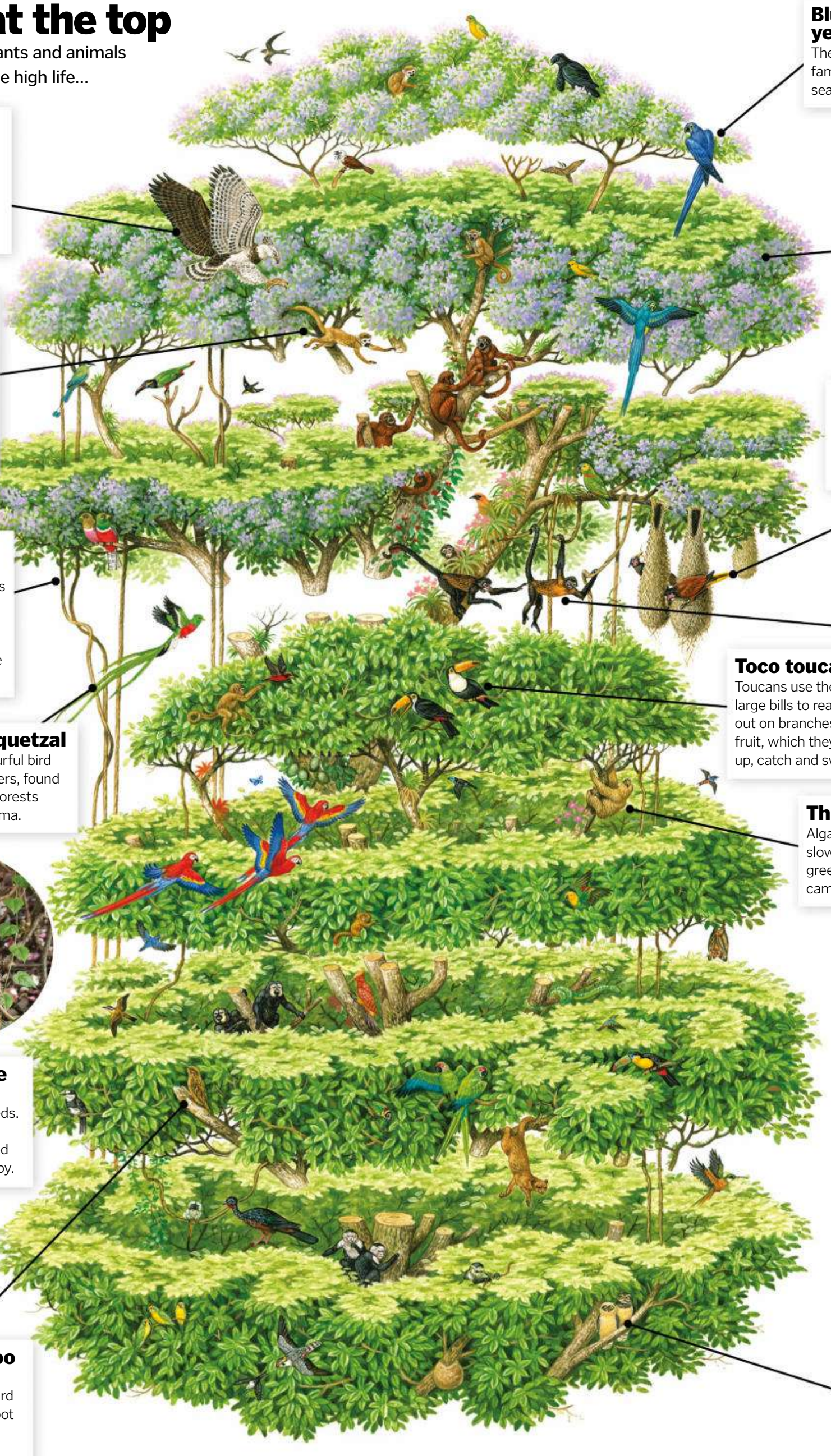
Paca
These rabbit-sized rodents use their strong jaws to open Brazil nut fruit and release their seeds.

Coati
Coatis move in groups across the forest floor. They climb to mid-level in the trees using their tails for balance.

Anaconda
This huge snake lives near rivers and swamps, hunting reptiles and small mammals, which it coils around to kill.

Living at the top

Many different plants and animals are adapted for the high life...



Harpy eagle
With a wing span of two metres, this is the largest rainforest bird of prey, feeding on monkeys and sloths in the canopy.

Squirrel monkey
Family groups of squirrel monkeys constantly move through the canopy to avoid being easy targets for passing birds of prey.

Liana
These vines germinate from seeds lodged high in trees. Their feeding roots dangle down in order to anchor them in the soil far below.

Resplendent quetzal
The quetzal is a colourful bird with long tail-streamers, found in the canopy of rainforests from Mexico to Panama.

Brazil nut tree
What we call 'Brazil nuts' are actually seeds. They develop inside hard, cannonball-sized fruit in the mid-canopy.

Common potoo
Clever camouflage makes this owl-like bird near-impossible to spot as it sleeps by day on top of a dead branch.

Blue-and-yellow macaw
These members of the parrot family often fly in large flocks, searching the canopy for ripe fruit.

Flowering trees
In tropical rainforests, some trees flower and others produce fruit all year, ensuring plentiful food for the many animals.

Crested oropendola
The pouch-like nests of these birds are a distinctive feature, dangling in groups from the ends of branches near rivers.

Spider monkey
Spider monkeys sometimes hang on their prehensile tails as they forage for fruit and nuts high in the canopy.

Toco toucan
Toucans use their large bills to reach far out on branches for fruit, which they toss up, catch and swallow.

Three-toed sloth
Algae growing on the fur of slow-moving sloths gives them a greenish colour which helps camouflage them amid the foliage.

Epiphytic bromeliad
Epiphytes, like this bromeliad, are sometimes called air plants because they grow in 'mid-air', with no connection to the soil.

Spectacled owl
These birds hunt at night among forest trees. They communicate with calls that sound like someone shaking metal sheeting.

© DK Images; Thinkstock

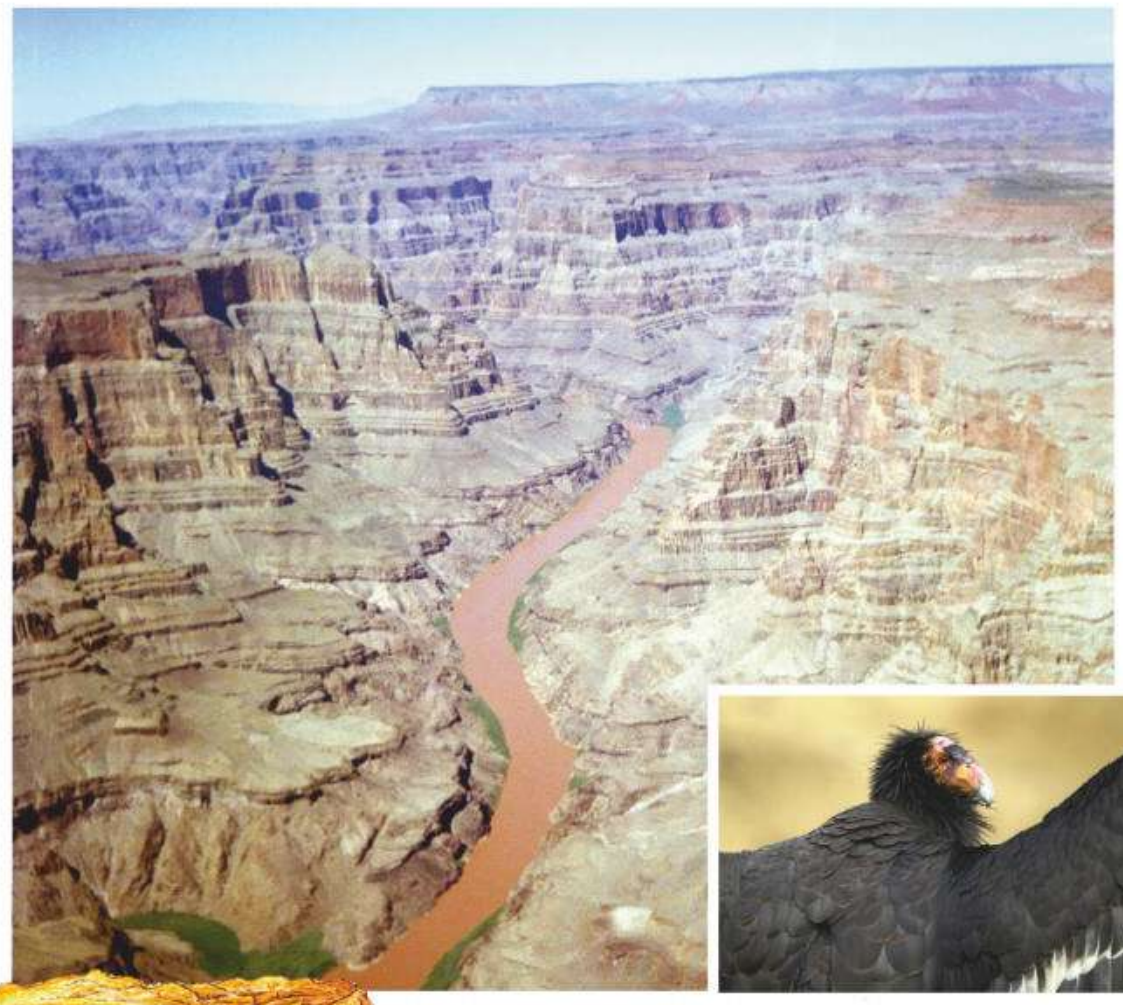
The Grand Canyon

One of the largest natural wonders of the world, this vast gorge was carved by water's erosive power

The exact processes that formed the Grand Canyon remain a compelling puzzle, but studies suggest this giant gorge was cut by flowing water just a few million years ago – a blink in geological time. The canyon's rocks have a much longer history – the oldest are around 2 billion years old.

Perhaps 30 to 70 million years ago, these rock layers were uplifted to form the high, flat Colorado Plateau. There are several theories explaining how and why this uplift happened. Around 5 to 6 million years ago, the Colorado River changed its course and began to carve down through the plateau.

The river uses sediment and rocks like chisels and sandpaper to chip away its channel. It has tremendous erosive power because it is fast flowing with a large volume, enabling it to carry a large amount of debris. Arizona's arid climate means rock is unprotected by vegetation, making it more susceptible to erosion.



High-rise wildlife

Five of North America's seven life zones – areas with similar plants and animals – appear within the Grand Canyon's 1.6-kilometre-high walls. While desert scrub like cacti are found close to the river, a spruce-fir forest covers the North Rim above 2,500 metres.

More than 1,500 plant, 355 bird, 89 mammal, 56 reptile and amphibian and 17 fish species are found around the canyon. Other wildlife species are rare or protected. For example, the California condor is one of the world's rarest birds.

Explore rock formations within the canyon

6 Hermit, Coconino, Toroweap and Kaibab
Shales, siltstones, limestones and sandstones deposited 270 to 280 million years ago in conditions ranging from desert to shallow seas.

5 Supai Group
Sandstones and siltstones deposited 285 to 315 million years ago along a coastal, low-lying plain. Coloured red by iron oxide.

4 Temple Butte, Redwall and Surprise Canyon
Fossil-containing rocks, such as limestones, formed from marine sediments deposited between 320 and 385 million years ago.

3 Tonto Group
Layers of sedimentary rocks like sandstone, limestone and shale deposited 505 to 525 million years ago in bays and lagoons.

2 Grand Canyon Supergroup
Rocks made of sediments laid down around 740 to 1,200 million years ago in a rift basin.

1 Vishnu Group
Formed around 2 billion years ago by heat and pressure as the North American continent collided with ancient islands.

The deeper you go, the older the Canyon's rocks get

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ESCAPE ROOM PSYCHOLOGY
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HOW TELESCOPES SEE SO FAR
+ EXPLORE A DEEP-SEA OIL RIG INSIDE A MICROCHIP GIANT CARGO PLANES

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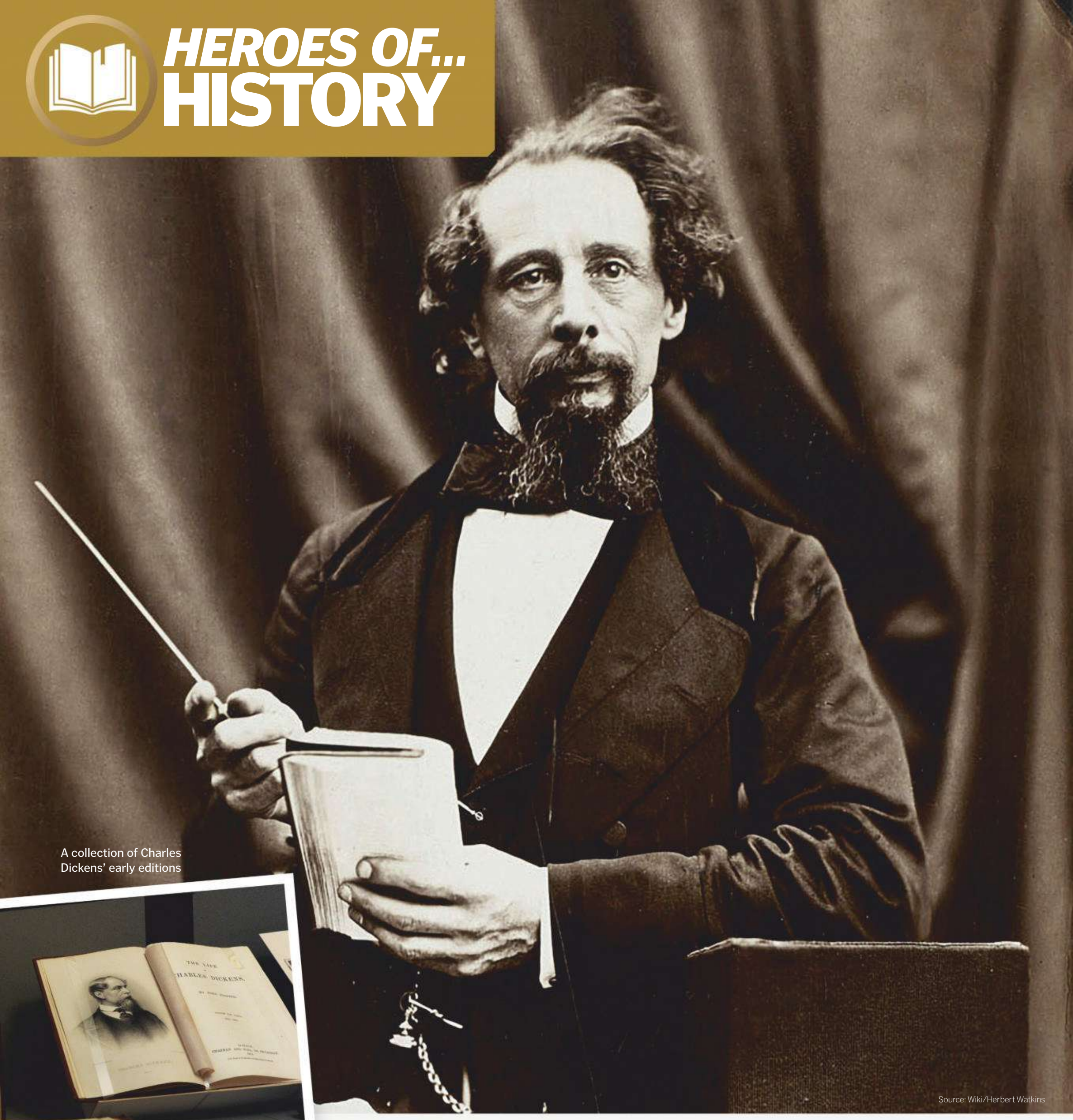


A collection of Charles Dickens' early editions

© Getty

Source: Wiki/Herbert Watkins

A life's work

The story of the storyteller

1812
Charles Dickens was born in Portsmouth, England, on 7 February to parents John and Elizabeth Dickens.

1824
12-year-old Dickens began working at Warren's boot-blacking factory. He earned six shillings (equivalent to about £17) a week putting labels on shoe polish jars.

1832
Taking to writing, Dickens started work as a journalist, writing stories and descriptive pieces for newspapers and magazines.

March 1836 to November 1837
Dickens' first novel was published in monthly instalments over 20 months. In *The Pickwick Papers*, his witty character depictions and writing style make him the most popular author within a few months.

Charles Dickens

This English novelist's best-selling stories were shaped by his own experiences

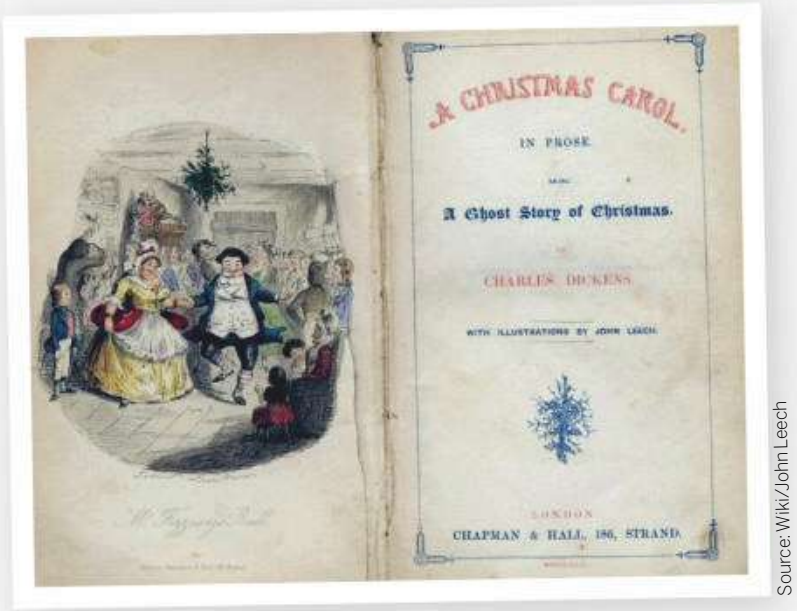
It has been 150 years since Charles Dickens died, 184 years since his first work was released to the public and 156 years since his last completed book came out. In all of this time, these novels have never been out of print. Dickens may have left us, but his work remains timeless, gripping the majority of those who open their pages.

Most people have read, watched or at least heard of Dickens' stories, but what makes him and his work so popular? Since he began novel writing in his 20s, Dickens constantly churned out quality classics. Year after year his awaiting fans were not left disappointed as their minds were fed with complex tales of romance, crime, hope and despair.

In the Victorian era he lived in, much of the work Dickens produced built on the literature before him. He was one of the first writers of the time to portray honest examples of working-class people, giving many something to relate to. He focused on unfolding the good and bad qualities of characters, which allowed his readers to follow their journeys and understand why they may have acted in the unusual or shocking ways that they did.

Any Dickens fans will know the diverse and outrageous characters that come to life between the pages. What was special about this novelist's ability in imagining these characters' stories is that it comes from his own life's path. From a young boy left to fend for himself in a workhouse to the wealthy figure he became through his writing successes, he knew what it was like to be seen in different lights. This deep understanding of his characters gave his fictional stories the strong element of believability that is needed in a good novel.

Over a century and a half later, Dickens' themes can be relevant to today's world problems. His words and imagery have been transformed further into the media of modern film, television and even musical adaptations. While his work may be set in a time alien to readers today, everyone can relate to the love, hardship and sense of family that pours from the narratives. It is this aspect that has carried Charles Dickens into the 21st century.



Source: Wiki/John Leech

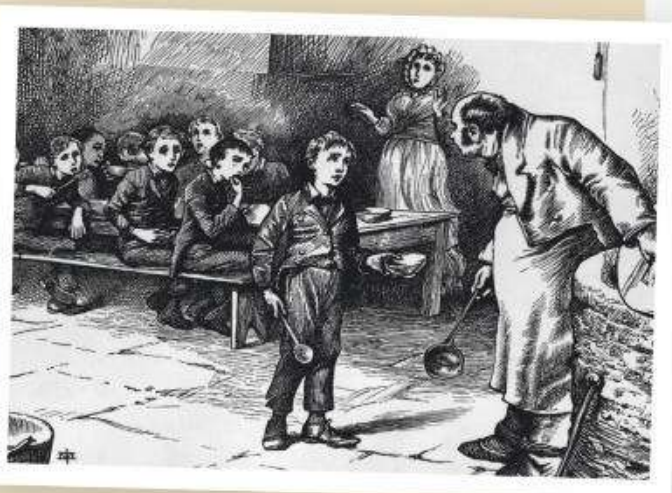
The first edition of Dickens' *A Christmas Carol*. This story continues to be revisited every December

THE BIG IDEA

How Dickens highlighted real-life problems

Dickens' variety of bestselling novels showcased his impressive storytelling skills. A huge part of Dickens' novel-writing talent involved bringing the words on the pages to life in the minds of his readers. In a compelling combination of escapism and realism, the scenes and underlying messages in a large number of Dickens' novels cover the social injustices of his time. While it can't be proved that he had any direct effect, many believe his works helped to influence the social reforms of Victorian England by making his readers more aware.

With careful detail in introducing the characters, Dickens allowed people from all walks of life to empathise with those living in poverty. Whether the enemy was the workhouse conditions and the law in *Oliver Twist*, the ignorance in *A Christmas Carol* or the prejudice and abuse in *Great Expectations*, he helped to show the world through the eyes of the less privileged.



© Getty

Dickens used illustrations in *Oliver Twist* to show the downfalls of the workhouse system

Five things to know about... Charles Dickens

1 Written by Boz

In some of his early work, Dickens wrote under the pseudonym Boz. This was a shortened version of a nickname he gave his brother, Moses. Humorously, he always spoke this name as if with a cold, 'Moses' becoming 'Boses'.

2 Lonely childhood

In desperate poverty, his father ended up in so much debt that the whole family, minus Charles and his sister, were sent to prison when Charles was 12.

3 Epileptic accounts

The novelist is thought to have suffered from epilepsy as a child and writes with accuracy about the condition in his books. Characters in *Bleak House*, *Oliver Twist* and *Our Mutual Friend* all suffer epileptic seizures.

4 Cliffhanger expert

In the time before television soaps, Dickens was serving episodic drama at the end of his books' chapters. This is because many of the novels were published in instalments and he wanted his readers to keenly await his next release.

5 Unfinished work

The day before he died, Dickens had spent the whole day writing *The Mystery of Edwin Drood*. The main character goes missing, but Dickens died before writing the ending. Who killed Edwin Drood will forever be a mystery.

1836
Dickens married Catherine Hogarth, the daughter of a well-known Scottish journalist, George Hogarth.

1837
Dickens and Hogarth had their first child. This is the first of seven sons and three daughters.

1837 to 1870
After his first success he wrote several further novels, with one left unfinished and published posthumously.

1858
Dickens and Hogarth separated. With rumours of an affair, Dickens was forced to write a notice of explanation in the *London Times* explaining the amicable split.

1865
A railway crash took place in Staplehurst, Kent, on 9 June, killing ten people and injuring 40 others. As a surviving passenger, Dickens was psychologically troubled for the rest of his life.

1870
On 9 June, following a stroke, Charles Dickens died at his home aged 58. This came as a great loss to all his readers.

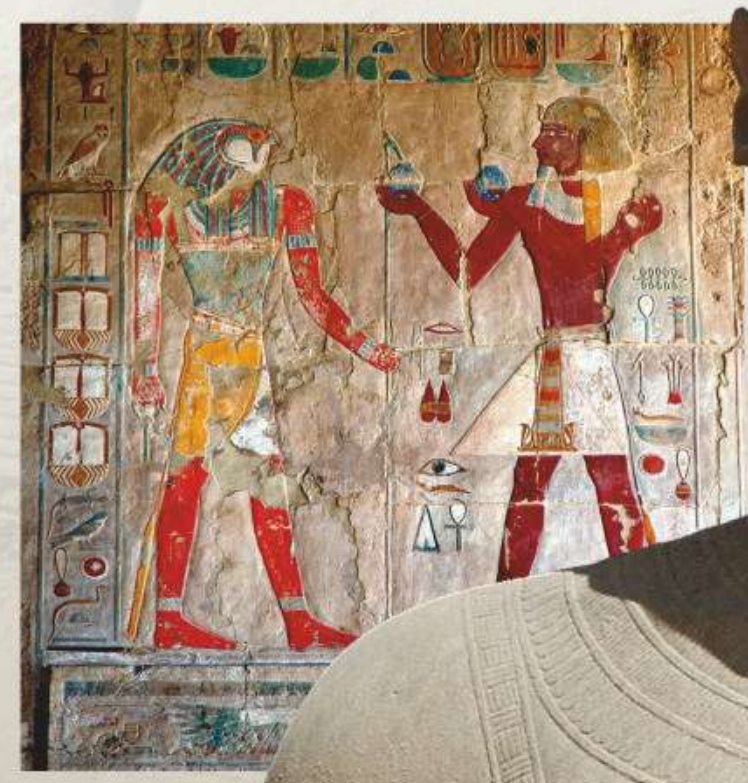
Hieroglyphs

Understanding the language of the gods

In order to learn the Egyptian script – known in ancient times as medu neter or 'words of god' – it is best to start with the alphabet, which is published here in full. As you start to recognise the words and names in the Egyptian script you begin to understand the excitement and adrenaline that historians must feel when deciphering an ancient text – by doing so you gain a unique insight into this incredible and mysterious civilisation.

The language is elaborate but also very accessible. It employs a series of grammatical structures that include verbs, nouns, negatives and particles; the Egyptians also used onomatopoeic words – for example 'cat' is written 'meow'. The language also contains a series of pictograms and phonograms, and is interspersed by determinatives. These are placed at the end of words in order to clarify their meaning.

The script has an abundance of symbols that reflect the natural world. Birds, mammals and trees often provide clues to the true meaning of the text. The language could be written left to right or right to left, and executed vertically or horizontally. The script is continuous and you can learn to separate the words by identifying the determinative or the strokes at the ends of each section.



"The language could be written left to right or right to left, and executed both vertically or horizontally"

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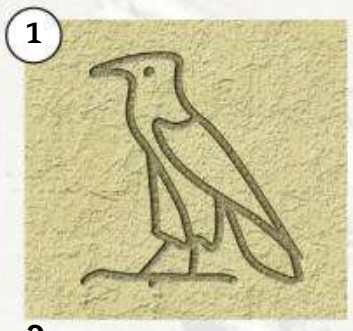
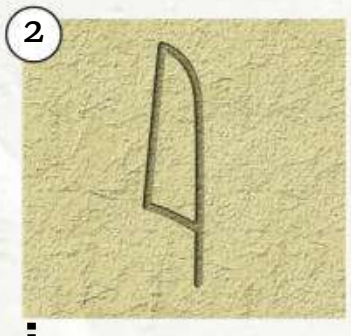
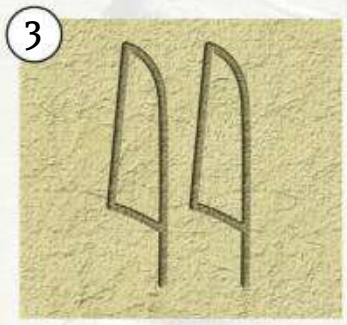


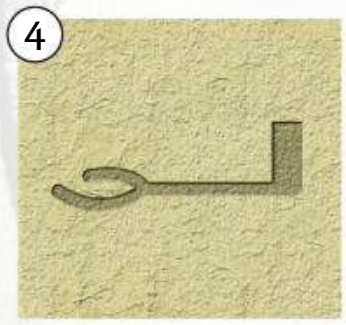
3 (‘ahhh’)
Egyptian vulture. This ominous bird is associated with both battlefields and graveyards.

2


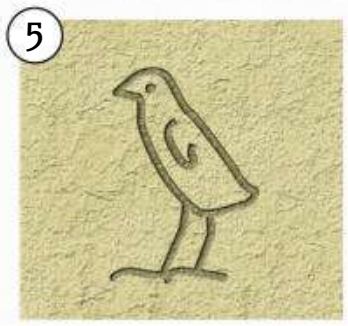
i
A flowering reed. The reed was used to make arrows and writing tools.

3


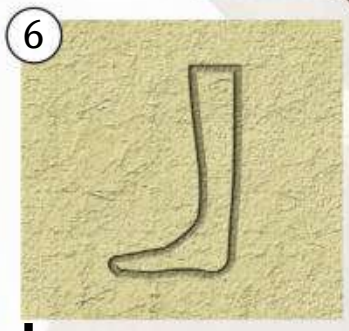
y (‘eee’)
Two flowering reeds or strokes that may have represented the sound of the wind on rushes.

4


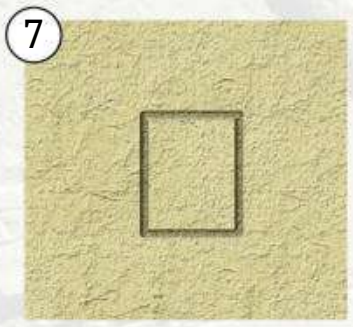
c (e)
The arm is often used in the Egyptian language to represent might or power.

5


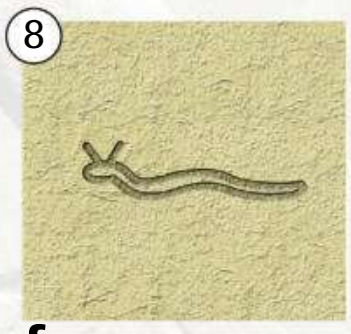
w (‘ooo’)
The quail chick adds a pleasant sound. It is often employed among signs that represent time.

6


b
The foot and leg. Egyptians became familiar with human anatomy through mummification.

7


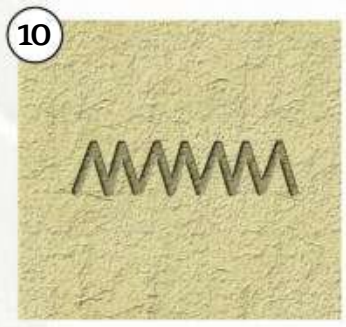
p
A seat, stool or throne. A sign in ancient Egyptian used frequently in royal titles.

8


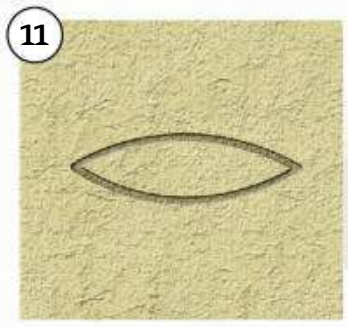
f
The horned viper is one of many snakes used in ancient Egyptian; it is often attached to a verb.

9

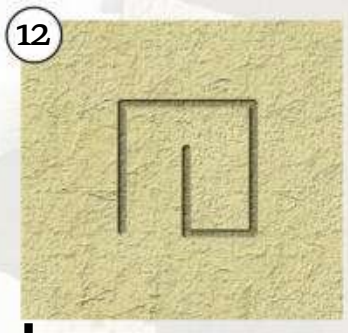
m
The owl is a common letter. It is rare to see the full face of any creature in imagery.

10


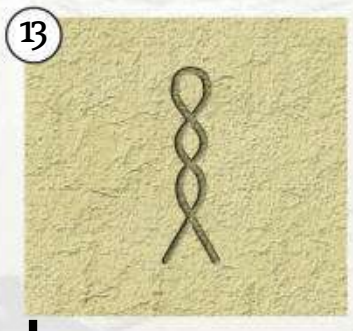
n
A water ripple is used to note transience; the words ‘to’ and ‘towards’ often contain this.

11


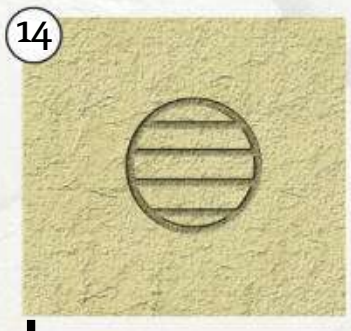
r
R is shown as a mouth. The letter is used in the words ‘recitation’, ‘to eat’ or ‘to speak’.

12


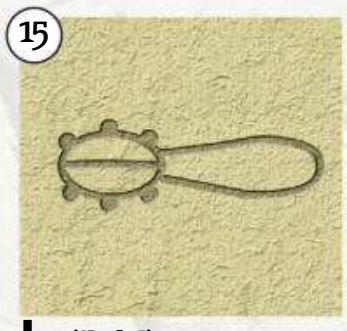
h
There are various ‘h’ sounds in the alphabet. This sign shows a rural shelter or a house.

13


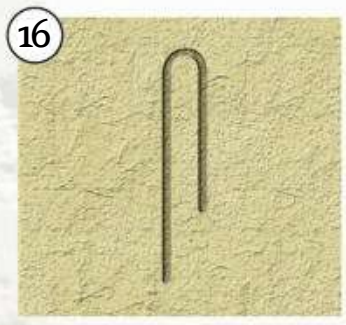
h (emphatic ‘h’)
A twisted piece of flax. Flax was a common material in ancient Egypt.

14


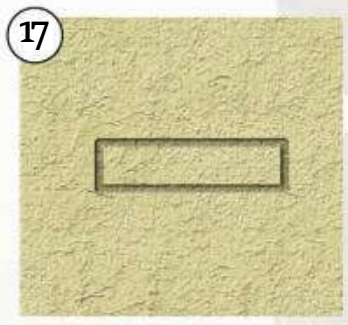
h (as in hock or lock)
The placenta can be found in many words, including those that deal with fortune and smell.

15


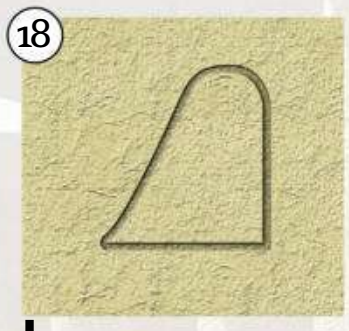
h (‘ich’)
The belly of an animal; this letter is used in words that denote the physical form.

16


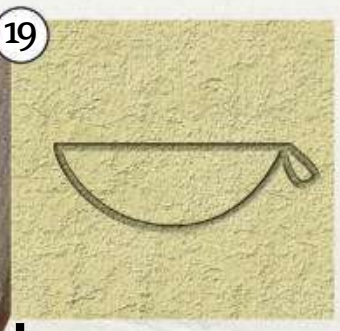
s
A door bolt and a folded sheet of cloth. It sounds like the English ‘s’. It has several different variations.

17


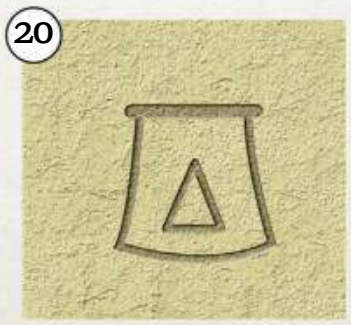
s (‘sh’)
Water features were a symbol of affluence, and upper-class villas were designed with pools.

18


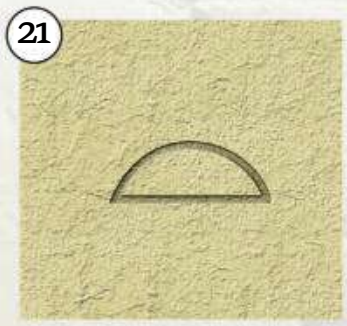
k (like ‘qu’ in quaint)
The hill sign is used in the words ‘tall’, ‘high’ and ‘exalted’, as well as ‘high ground’ or ‘summit’.

19


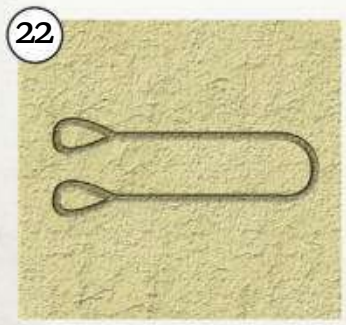
k
A reed basket with a handle. This can be used in many contexts and is employed as the pronoun ‘you’.

20


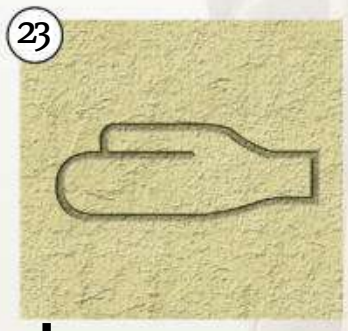
g
The Egyptians were fond of wine. The sign of this jar stand is transliterated with a hard ‘g’.

21


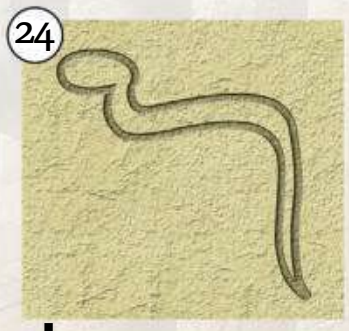
t
Bread was the most basic food in Egypt; here we see a small loaf of oven-baked bread.

22


t (‘tsh’)
Tethering rope. The Egyptians had 38 signs for ropes and baskets. ‘t’ is also a pronoun.

23


d
Human hand. There are 63 signs for the human body. This sign was used for words of action.

24


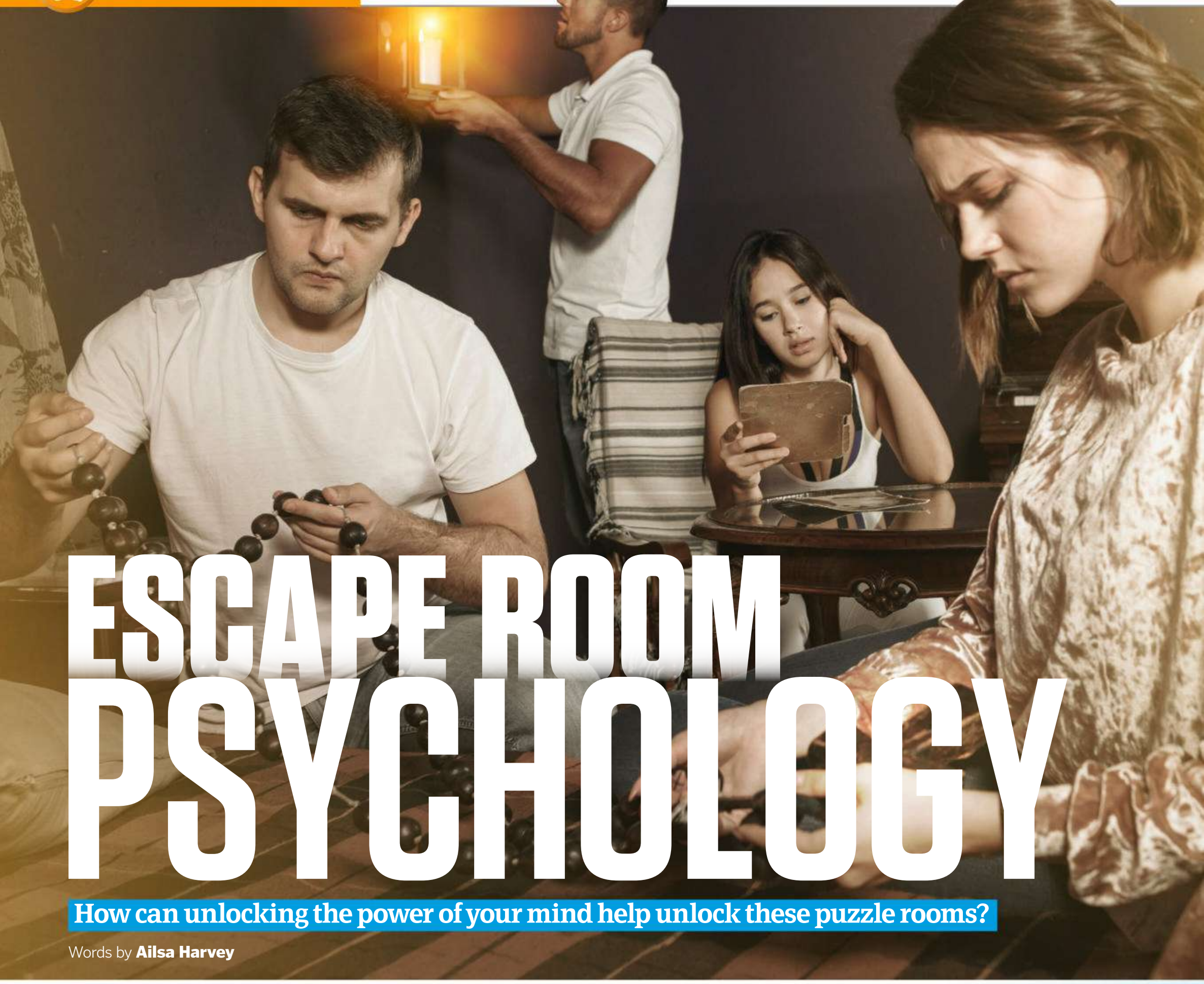
d (dj)
Snakes were feared creatures. This letter is often used in words of declaration or recitation.

The Rosetta Stone

The ultimate codebreaker

The Rosetta Stone is viewed as one of the most remarkable finds of the ancient world. It was discovered in Egypt in 1799. The top and middle sections of the stone are carved with hieroglyphs and demotic – a variation of the Egyptian text. The lower section is in Greek script, which ultimately acted as a codebreaker for the upper sections. A series of scholars were involved in the race to decipher the hieroglyphic code, but the breakthrough is credited to Jean-François Champollion. Champollion used the Greek portion of the text to reveal the secret language of the pharaohs.

The missing link
This section helped decipher the hieroglyphs.



ESCAPE ROOM PSYCHOLOGY

How can unlocking the power of your mind help unlock these puzzle rooms?

Words by **Ailsa Harvey**

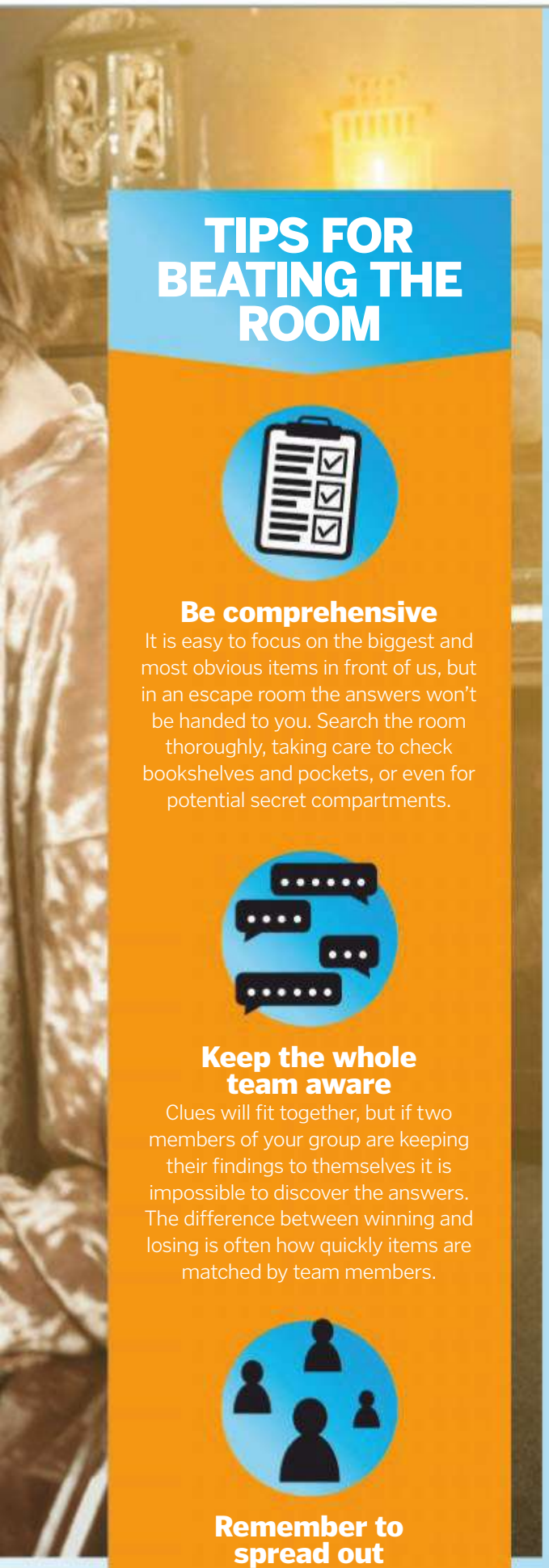
Your time starts… now. Trapped in a locked room with just 60 minutes ticking down on the clock, where do you begin in the search for freedom? It might not be a life or death situation, but the unfamiliar surroundings and growing intensity could convince you otherwise. It is this realistic urgency that gets you and your team springing into action in a problem-solving frenzy.

This is an escape room – a live-action game that puts your actions in charge of the outcome. The clues are all around you. You just need to know where to look. Taking on the room puts your brain to the test as you battle against the time pressure, confinement and puzzles of ranging complexity. A good team will be able to work well together, understanding each other's strengths and weaknesses and using them to their advantage. These unique missions give players the opportunity to be the heroes of the event. Everybody goes into these rooms hopeful that their team will be leaving triumphant, but in reality many succumb to the psychological challenges that come with the desperation to escape and beat the challenge.

Being locked in a room may seem like an unusual recreational activity choice, so what is it about this experience that gives us such a thrill? Forced to think quickly, teams usually keep bouncing ideas off each other as they pace around the limited space. This movement in the body and brain has been shown to create a similar effect to going for a walk, as it releases the happy hormone, dopamine. Combined with the adrenaline released during an intense race against time, the energy can be contagious. As it passes through the team, the whole group's mood can be lifted, even in those who fail.

Clues don't always rely on a sharp eye. With thousands of escape rooms multiplying around the world, escape room managers are finding new ways to engage players. Many involve a range of sensory clues, stimulation that helps to awaken the body and keep different pathways in the brain active.

Above all, escape rooms provide an area to get to know your friends or coworkers better. You may even be playing along with strangers. Finding out how other people's brains work, learning from each other and working as a team to achieve a common goal can give people a sense of purpose, build relationships and hopefully leave people walking away filled with pride and accomplishment.



TIPS FOR BEATING THE ROOM

Be comprehensive

It is easy to focus on the biggest and most obvious items in front of us, but in an escape room the answers won't be handed to you. Search the room thoroughly, taking care to check bookshelves and pockets, or even for potential secret compartments.

Keep the whole team aware

Clues will fit together, but if two members of your group are keeping their findings to themselves it is impossible to discover the answers. The difference between winning and losing is often how quickly items are matched by team members.

Remember to spread out

If everyone groups around the same puzzle, progress is much more limited. Some people make the mistake of spectating any interesting advancements when there is more that needs to be done. The more tasks that are being worked on, the quicker the escape will be.

Organisation is key

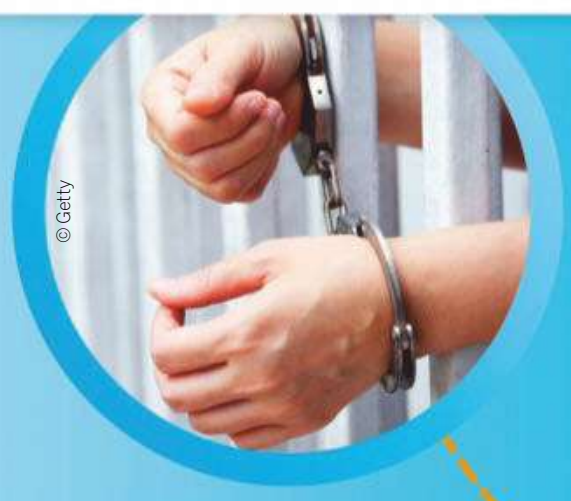
The brain works better on puzzles when it can see all the elements it is working with. Keep all related objects in one place so they are easy to find and process.

Escape rooms around the world

Would you be able to beat them all?

Lockin
Manchester, England

Not only is this an escape mission, but an attempt to find the president's son. In other rooms a sense of urgency is created by handcuffing two team members to a cell. The escape rooms at Lockin help players live the situation in an environment between real life and virtual reality.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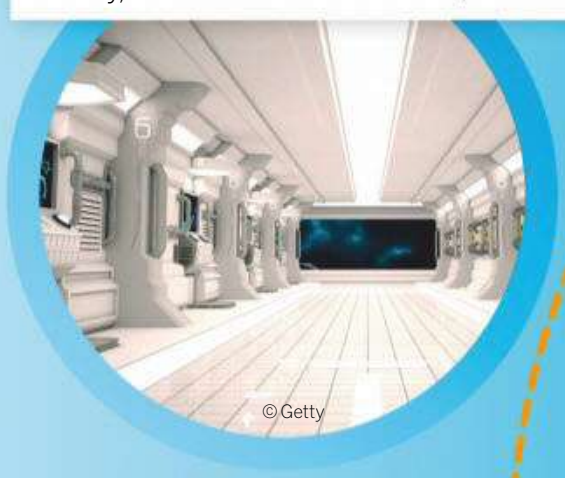
Sherlocked
Amsterdam, Netherlands

Here there are two opposing experiences to choose from. Do you want to escape or break in? In 'The Architect' you have 60 minutes to uncover the world's most powerful secrets, while in 'The Vault' you work your way into a secret safe.

The Escape Game
17 US cities

With a range of themes, this escape room immerses you in realistic settings, from escaping dingy prisons to navigating high-tech spaceships. For the most recent rooms all your senses need to be ready, as some clues need to be sniffed out.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Palace Games
California, US

Palace Games offers you the chance to go against the original escape artist, Harry Houdini. Designed by the man himself in 1915, The Great Houdini Escape Room lets you take on the ultimate challenge of cracking the legendary artist's own puzzles.

Escapology
Worldwide

The wide range of challenge choices in over 50 locations around the world makes this one of the most rapidly growing franchises. Whether it's the novelty Scooby Doo theme or the high-difficulty submarine escape, their huge range tries to capture the imagination of everyone.

© Getty

"The whole group's mood can be lifted, even in those who fail"

THE SCIENCE OF ESCAPE

How does the mind cope with code cracking?

CONQUERING COMMON PUZZLES

What types of puzzles are found in these rooms?

NUMERICAL

Numerical clues are not always found in a straightforward equation. Sometimes the hardest part of a numerical puzzle is finding the puzzle itself. One example of these puzzles involves equations using colours, for example (red + green - yellow) x orange'. The only way for this to work is to find these colour clues around the room and figure out what numbers the colours correspond to. Whether they are real items or a decorative picture, search for items and clues that pair up.

DEXTEROUS

This is a puzzle designed for someone with skilful control, balance, the ability to multitask and plan ahead. Defined by their intricate pathways and confusing networks, maze boards are a common find in escape rooms. Sometimes larger versions require four people to take a corner and remain steady in times of stress. A key is usually found at the centre, and when the team successfully reaches the maze's core they unlock a new aspect of the room.

LOGICAL

Some of the most frustrating puzzles can test your logic rather than your knowledge. Forcing you to envisage words' usage and meanings in new ways, riddles trip a lot of people up in escape rooms. The two main types are enigma riddles, which are likely to be metaphorical, or conundrums, which test your wordplay ability. The beauty of escape rooms is the high likelihood that the answer is in the room. Working backwards could help you out, so keep a look out for objects that could fit – or, if you have found a series of letters, what words do they make?

VISUAL

Paying attention to every detail is crucial. But once you've seen everything, take time to look again. Observe the surroundings of the room in new ways, because you never know where clues might be hidden. Optical illusions are the perfect way to hide the answers right in front of the players' eyes. Your eyes can sometimes be tricked into not seeing words if they are hidden in the spaces of a picture or blend into a similar background.

COMBINATIONAL

Once you have rushed around the room trying to answer all the puzzles, you may be left with multiple answers. Items such as padlocks can be ideal for putting the findings together and progressing to the next stage. Make sure you try all combinations. If it still doesn't open, it may be time to revisit the numerical puzzles again.

Hard-easy effect
With the pressure of escape, your mind may work to overcomplicate the puzzles. Your team might miss the obvious answers by looking for something more abstract.

Forward planning
We often think into the future, planning the next steps ahead. In these rooms events can quickly steer away from what we thought we were working towards. The brain is forced to act quick to modify planned behaviour.

Thinking outside the box
Getting the job done is easier to do when you know what you're doing. The challenge of escape rooms is accessing new areas of the brain. By encouraging the creative problem-solving aspects of our minds, players are not just finding the answers, but discovering what they are answering.

Stressing out
The brain's stress hormone, cortisol, can be released in these high-intensity situations. Affecting performance, this stress is not ideal for problem solving and can lead to impulse actions and poor memory.

AR ZONE! SCAN HERE

Availability heuristic
Time is of the essence in escape rooms. Because you are required to think of solutions quickly, the brain may take a mental shortcut. In a strategy called availability heuristic, your brain chooses information that you can think of quickly. Escape rooms have undertaken much planning to present new challenges, and this potential solution will more often than not be the answer.

Survival mode
Some escape rooms go to greater lengths to immerse you in the story than others. In the more believable examples, you can begin to convince yourself of the need to escape. When the body is flooded with adrenaline, it can focus the brain and help it perform quicker.

© Illustration by Nicholas Forder

Selective perception
You've got an inkling of where the clues are taking you and are determined to find other clues that follow the same path. This is called selective perception and might cause you to overlook other vital and unexpected clues.

Information storage
While clues and answers are dispersed around the room, they are likely to come together in the end. In order to solve the steps, players must keep each finding in the back of their mind. You never know when links between them will need to be made.

Making the team
What are the best roles to assign to each member in order to succeed?

Leader
This person is usually the extrovert of the group. Good at guiding the team and keeping the group on track, they oversee the entire team and general progress.

Finder
There will nearly always be someone with a keen eye who is best at finding new clues and information. They might not know what they mean, but they will be first to spot hints.

Worker
To cover all ground, teams need someone who has the patience to cover the painstaking tasks of looking through all the books or sorting all the puzzle pieces.

Thinker
The natural puzzler of the group puts their brains to good use as the main thinker. Slotting together the pieces found by other members, they focus a lot of their attention on cracking the codes.

Leaper
The logic leaper won't follow the average cognitive paths. Coming up with the abstract ideas, they are there to think outside the box. A lot of the time they will be wrong, but when others are stumped their imaginative ideas can pay off.

Challenger
It may feel like the challenger is against you, but they are essential in reasoning with, and rethinking, ideas. They help to sort the ridiculous from the possible and fine-tune the plan.

© Getty

The problems with human cloning

What's stopping scientists from creating lab-grown people?

Words by **Scott Dutfield**

In 2017 Chinese scientists used a robot to move the nucleus out of one cell and transfer it into another to clone pigs

What if there were two of you? You could finish your chores and errands in half the time, juggle those overlapping social engagements or let one of you work while the other takes a mini vacation. In theory the idea of cloning ourselves might seem like a no-brainer, but in actuality, creating human clones is rife with brain-stretching scientific and moral obstacles.

Since the creation of Dolly, the first cloned mammal, the last 20 years have been filled with many examples of DNA being taken from different species of animals, such as rabbits, rats, dogs and horses, and successfully creating a copy. Although the science works for those species, it's not a one-size-fits-all technique.

One of the main challenges in human reproductive cloning is replicating our life span. The genetic information that is used as the instruction manual for cloning comes from the nucleus in an adult cell. As adult cells grow and divide, over time the end portions of our chromosomes, known as telomeres, shorten a little with each division. By the time we reach adulthood chromosome telomeres are quite short, so after implanting adult chromosomes into an embryonic egg, the chromosomes shorten beyond the normal amount. This shortening would lead to clones developing life-threatening conditions and typically halving their life span when compared to their DNA donors, as seen in animal studies. Other biological hurdles occur during the process of extracting the nucleus from the donor egg. For example, during removal vital proteins within the cell that are important for cell division can also be unwittingly removed.

© Getty

Are they among us?

Could it be possible that there is a human clone among us? Back in 2002 biotech company Clonaid claimed to have achieved the work of science fiction and birthed the world's first cloned baby, later known as 'Eve'. Following sweeping newspaper headlines, public interest mounted about the real-life possibilities of human cloning. However, something didn't add up about Clonaid's medical revelation. Clonaid had supposedly taken the DNA from the donor 'mother' to be implanted into the DNA-vacant egg and reimplanted into the donor, resulting in a successful pregnancy. What Clonaid didn't provide, however, was any medical or photographic evidence of Eve for peer review, leaving both the media, scientists and the public with no way of knowing for sure their claim was true, although it was generally concluded to be false.

Human cloning is also a moral and ethical minefield. Would human clones become enslaved and be deemed sub-human? Is bringing the DNA of a deceased loved one back to life the right thing to do? Along with the scientific obstacles of human cloning, the dilemmas it poses are challenging to overcome. As it currently stands we are not technologically advanced nor morally prepared enough to bring biological doppelgängers into the world.

The road to human cloning

Discover the milestones science has made in cloning technology

1952
Scientists showed they could remove the nucleus of an embryonic frog cell and transfer it to an enucleated egg cell.

1963
The first cloned fish, a carp, is created from a DNA transfer by Chinese scientists.

1996
Dolly the sheep is born, the first mammal to be cloned from an adult cell.

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1998
50 mice are reportedly cloned from a single mouse over several generations.

2001
Cats are added to the list of cloned animals when American scientists created 'CC'. However, she differed physically from her 'mother'.

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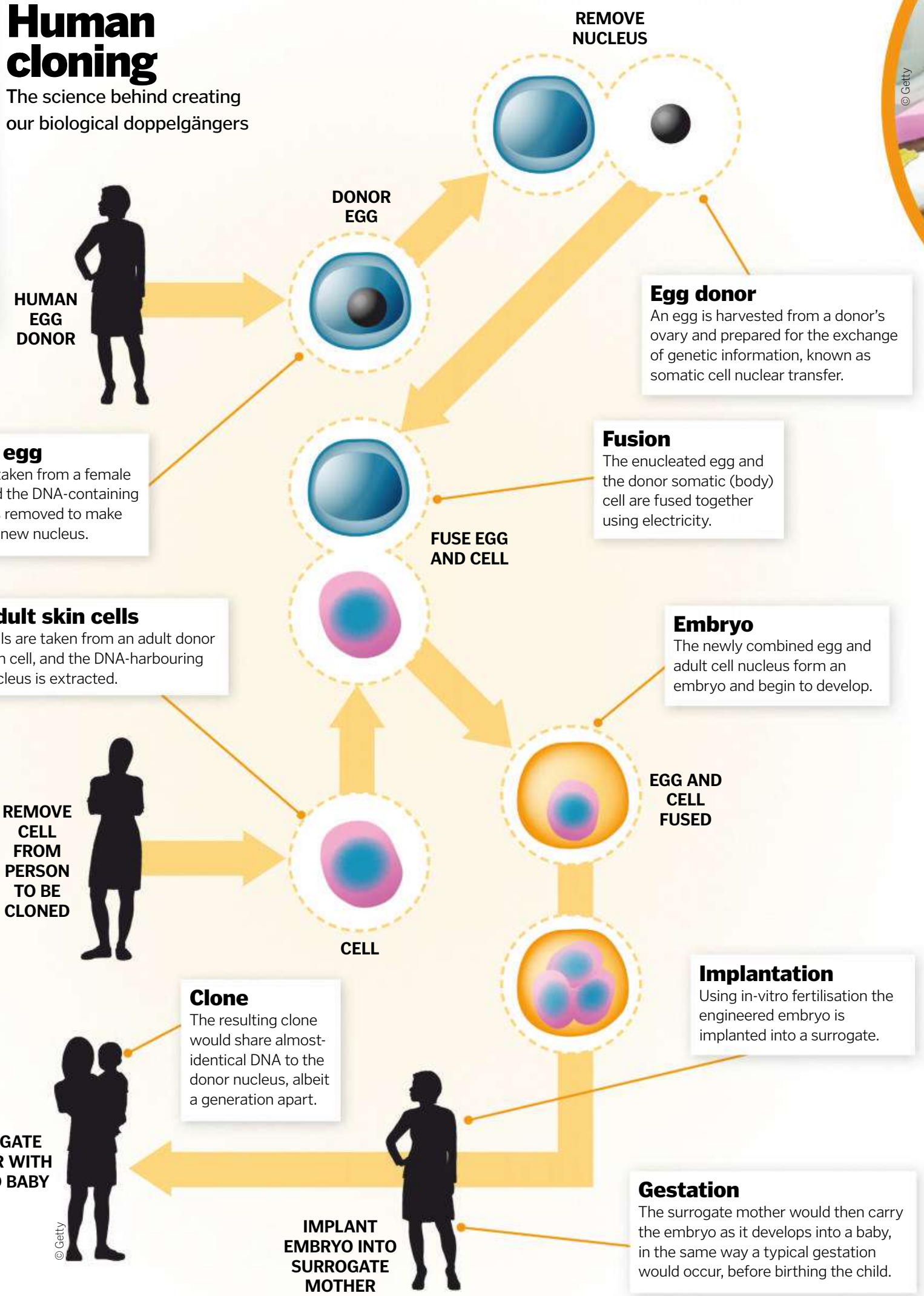
Human cloning

The science behind creating our biological doppelgängers


REMOVE NUCLEUS
DONOR EGG
HUMAN EGG DONOR
Egg donor
An egg is harvested from a donor's ovary and prepared for the exchange of genetic information, known as somatic cell nuclear transfer.
Donor egg
Eggs are taken from a female donor and the DNA-containing nucleus is removed to make way for a new nucleus.
Fusion
The enucleated egg and the donor somatic (body) cell are fused together using electricity.
FUSE EGG AND CELL
Adult skin cells
Cells are taken from an adult donor skin cell, and the DNA-harbouring nucleus is extracted.
Embryo
The newly combined egg and adult cell nucleus form an embryo and begin to develop.
REMOVE CELL FROM PERSON TO BE CLONED
EGG AND CELL FUSED
CELL
Clone
The resulting clone would share almost-identical DNA to the donor nucleus, albeit a generation apart.
Implantation
Using in-vitro fertilisation the engineered embryo is implanted into a surrogate.
SURROGATE MOTHER WITH CLONED BABY
IMPLANT EMBRYO INTO SURROGATE MOTHER
Gestation
The surrogate mother would then carry the embryo as it develops into a baby, in the same way a typical gestation would occur, before birthing the child.
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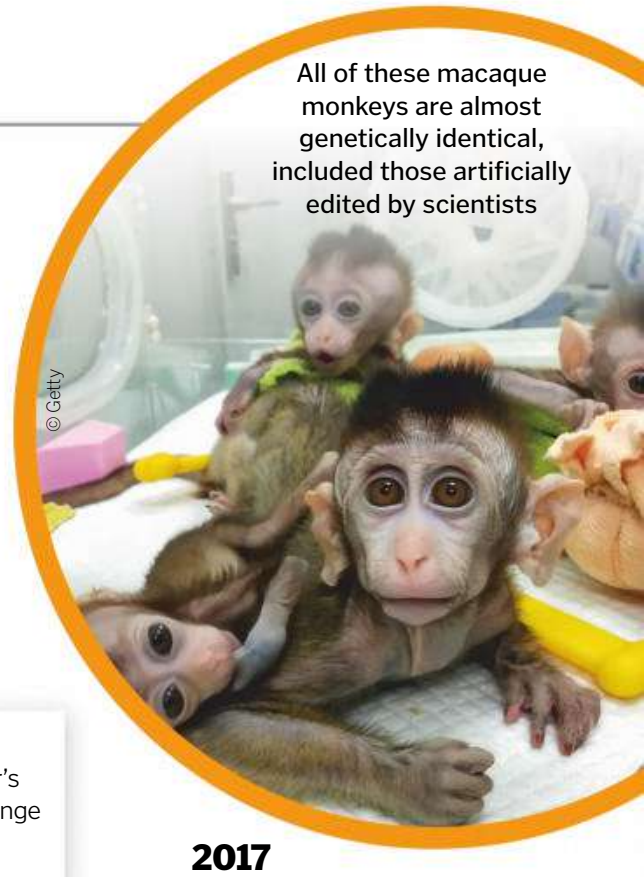
All of these macaque monkeys are almost genetically identical, included those artificially edited by scientists
© Getty

2017
Going ape for cloning

One of the proposed benefits of cloning is the ability to assist in the treatment of human conditions such as Alzheimer's disease and cystic fibrosis. A couple of years ago Chinese scientists made a huge advance in the potential of cloning when they created Zhong Zhong and Hua Hua, two macaque monkeys. Using the same method of somatic cell nuclear transfer used in the creation of Dolly the sheep back in 1996, genetic information from an adult cell was transferred into an enucleated egg and implanted into a surrogate.

Why this is a potential game changer for the science of cloning is down to the comparable higher cognitive functions monkeys share with humans. Having achieved success in cloning, researchers at the Institute of Neuroscience in Shanghai have now used the technique to clone another macaque monkey which had been genetically modified to disable a gene crucial for sleep. The resulting five clones were found to share the edited mutation and thus developed the same sleep disruption, therefore shedding light on the role of gene expression and disease development.

2001
A six-cell cloned human embryo is produced to harvest the developing stem cells.

2002
The first cloned rat, 'Ralph', is born. From 129 implanted embryos, only three pups were born.

February 2003
Dolly is euthanised after developing a lung disease at just 6.5 years old – half the age of a naturally born sheep.

2005
The world's first cloned dog named Snuppy, an Afghan hound, is born in South Korea.

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2013
Human skin cells are reprogrammed into their original embryonic state in America.

2014
Scientists placed an adult human skin cell nucleus into the enucleated egg and began to start embryonic development.

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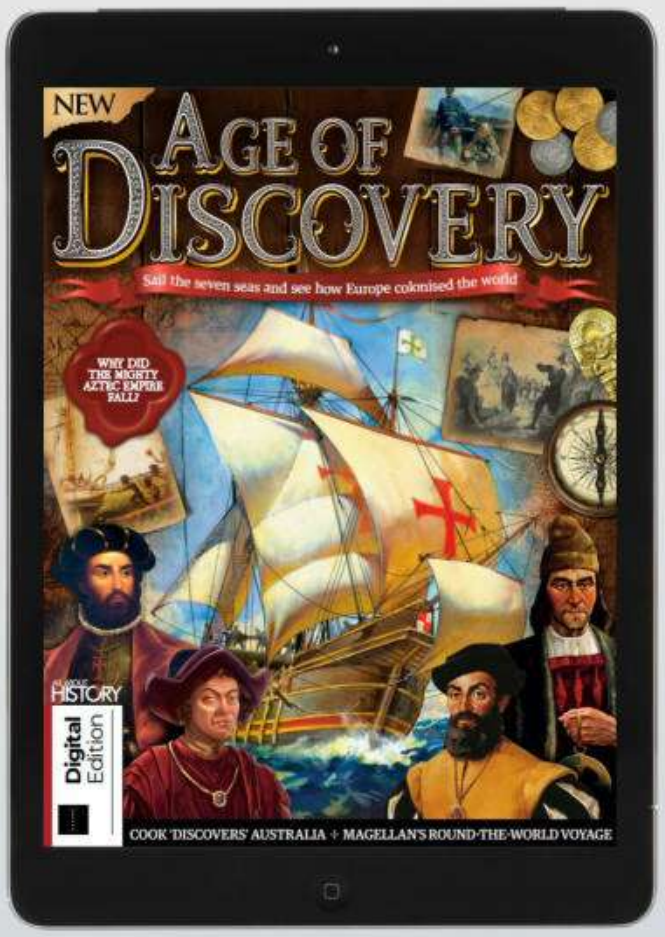
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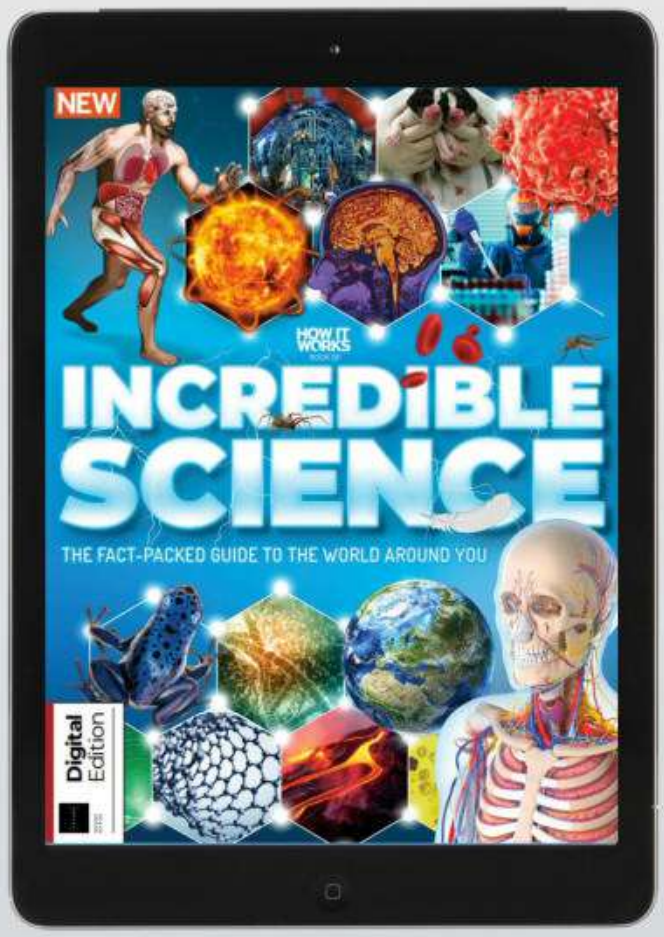
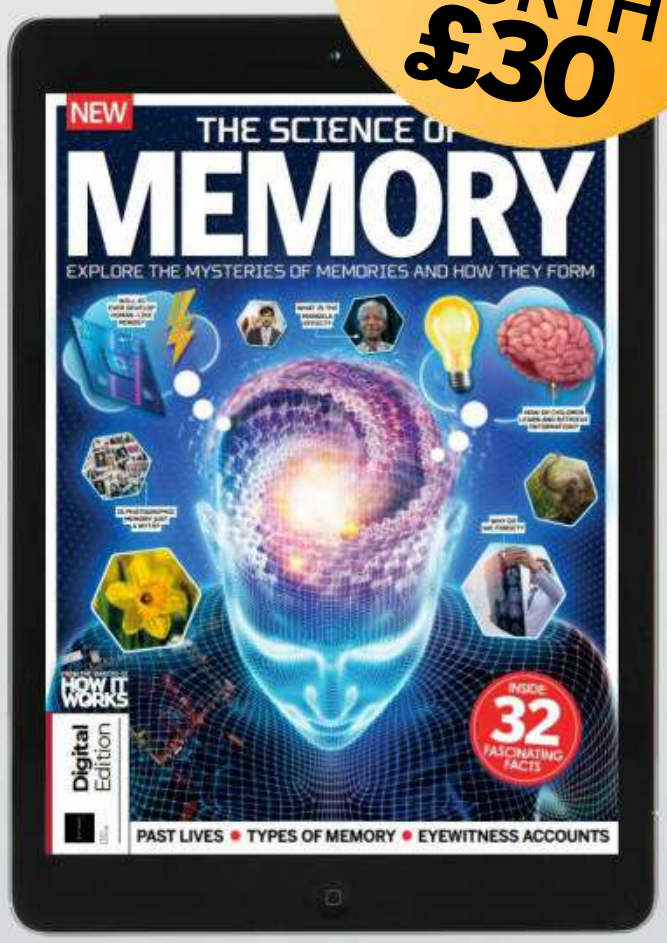


Incredible Science

Journey from our early beginnings as a species, how we came to be and how our immune systems, emotions and fears developed. Meet some of science's greatest minds, explore the massive power behind nuclear fusion and the endless possibilities offered by quantum mechanics, before stepping into a future where many diseases are a thing of the past. Could cloning yourself be more than just the stuff of science fiction? A world of incredible science awaits you inside this book.


NEW
THE SCIENCE OF
MEMORY
EXPLORE THE MYSTERIES OF MEMORIES AND HOW THEY FORM
HOW IT WORKS
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INSIDE: 32 FASCINATING FACTS
PAST LIVES • TYPES OF MEMORY • EYEWITNESS ACCOUNTS

The Science of Memory

From our earliest recollections of childhood to what we did last night, our memories make us who we are. Yet how much do we actually know about memory? Delve inside the inner workings of the brain, examine the effects of trauma on our ability to retrieve information and meet a woman who can't remember part of her life. Explore the science of savant minds, past lives and animal memory before discovering the mission to implant memories into robots of the future.

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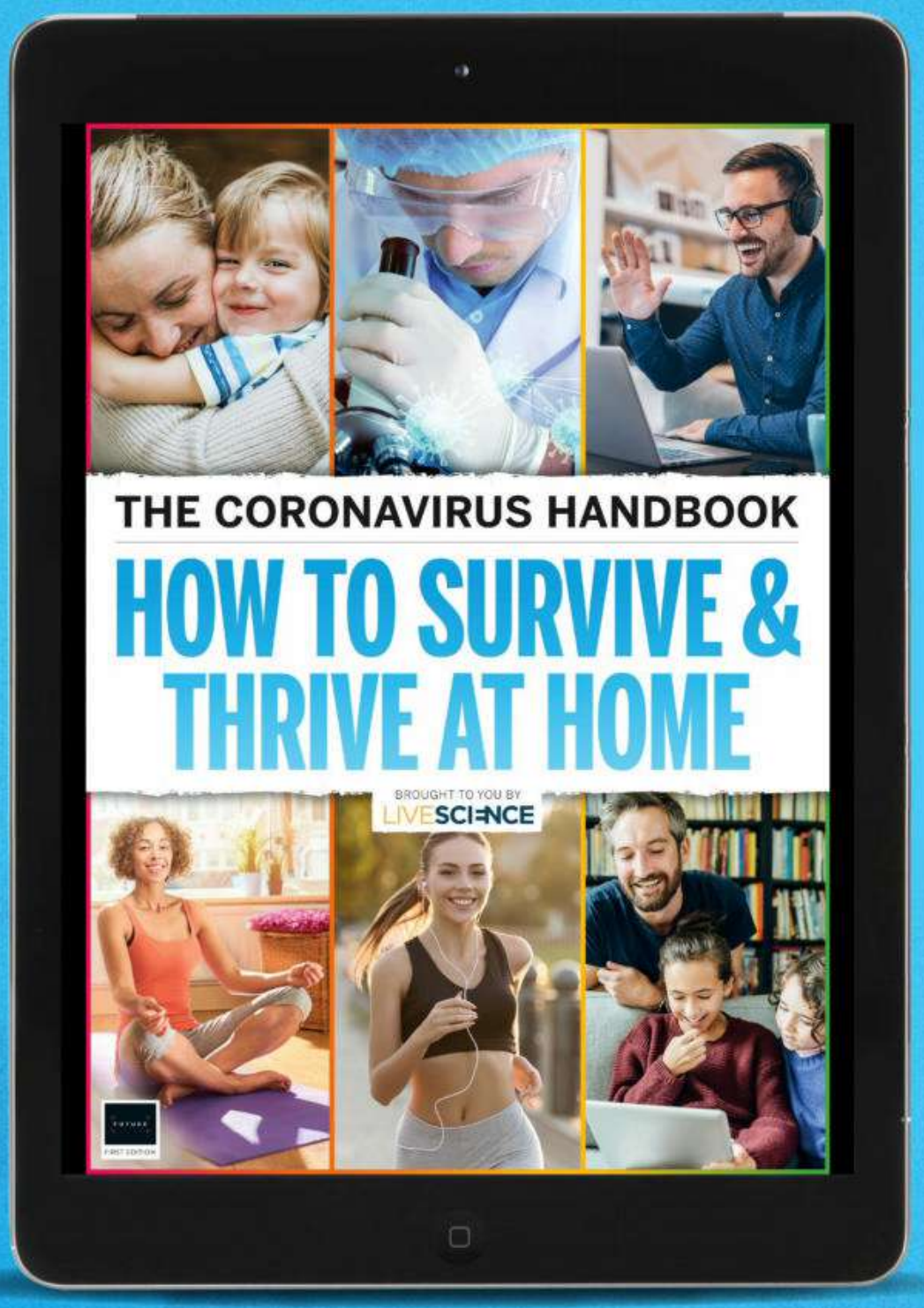
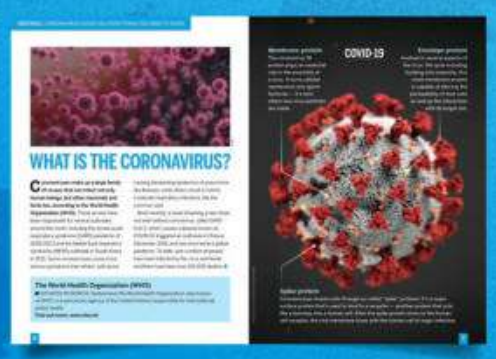
THE CORONAVIRUS HANDBOOK

How to Survive & Thrive at Home



- *What are the symptoms of coronavirus?*
- *How can I stop it from spreading?*
- *How can I protect my family?*
- *What is the best way of homeschooling my children?*
- *How can I work effectively from home?*
- *What's the best way of staying fit and healthy, physically and mentally?*

In this handbook you'll find the answers to all these questions and more as **Live Science** keeps you up to date on the latest information on the pandemic. Providing practical advice on everything from creating an office space and finding a healthy balance between parenting and worklife to choosing the right diet and pastimes for you and your family, **Live Science** ensures you thrive and survive at home during these challenging times.



CHECKLIST:
WHAT'S THE BEST WAY TO PREVENT CATCHING OR SPREADING THE VIRUS?
PRACTICE GOOD HYGIENE AND HEALTH HABITS
HOW TO WASH YOUR HANDS

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The Coronet Cluster as observed in infrared by the Spitzer Space Telescope

© NASA

Telescopes are a wide-ranging form of technology used by scientists, astronomers and civilians alike to observe remote objects by the collection of electromagnetic radiation

How do telescopes see stars?

From their origins as simple handheld instruments formed from a crude coupling of a convex objective lens and concave eyepiece used to observe distant objects to their utilisation in collecting and monitoring electromagnetic radiation emanating from distant space phenomena, telescopes are one of the human race's most groundbreaking inventions. Indeed, now there are telescopes which can monitor, record and image almost all wavelengths of the electromagnetic spectrum – including those with no visible light – and their usage is widening our understanding of the world around us and the far-flung reaches of space. Here we take a look at some of the telescope types in use today, exploring how they work and what they are discovering.

Finderscope
A smaller telescope with a wider field of view designed to allow quicker spotting of the chosen target.

Light shade
Like a camera lens hood, it's designed to block out unwanted light sources.

Eyepiece
The 'optical out' for the target's light source, it's designed to the scale of the human eye.

Focuser knobs
Similar to an adjustable camera lens – good for making incremental adjustments to provide better image clarity.

Finderscope bracket
This often-detachable bracket holds the finderscope in place.

Main body
The part of the telescope system where light is reflected, refracted – or both – to a focus point.

Counterweight
A simple counterweight to aid stability.

Latitude adjustment T-bolts
Twin bolts used to stabilise latitude.

Hubble, Spitzer and Chandra joined forces to create this amazing image of Messier 82, which is about 12 million light years from Earth

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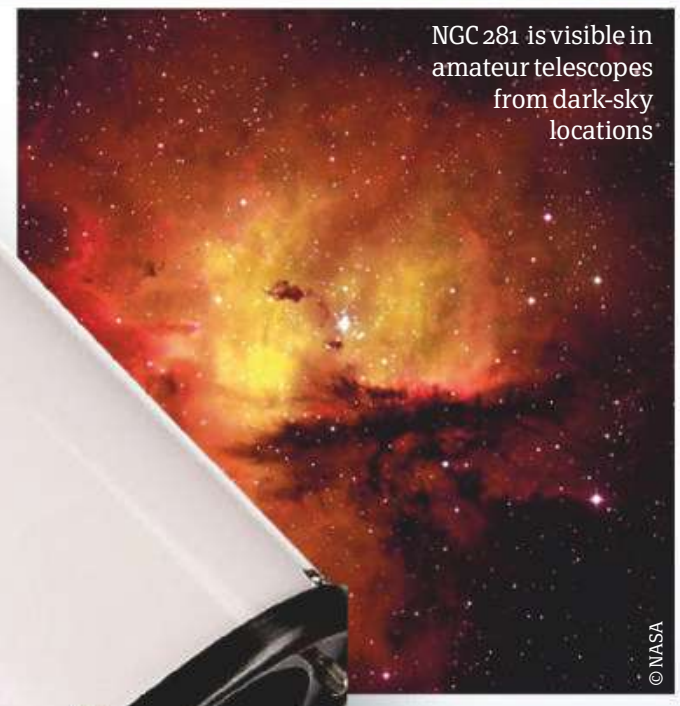


NGC 281 is visible in amateur telescopes from dark-sky locations

© NASA

The telescope at Kitt Peak National Observatory, Arizona

Azimuth adjustment knob
A crucial mechanism used to adjust the telescope to the direction of the celestial target.

The optical telescope

Since its creation in 1608 the optical telescope has made the close viewing of far-away things much easier. But how do they work?

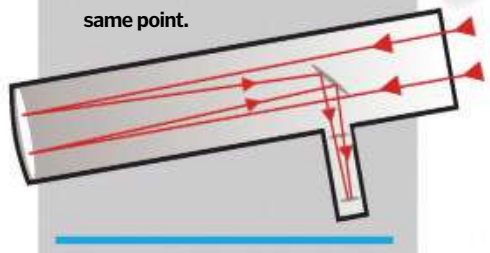
The standard optical telescope works by reflecting or refracting large quantities of light from the visible part of the electromagnetic spectrum to a focus point observable through an eyepiece. In essence, the large objective lens or primary mirror of the telescope collects large quantities of light from whatever it is targeted at. By focusing that light on a small eyepiece lens, the image formed is magnified across the user's retina, making it appear closer and considerably larger than it actually is. Therefore the power of any given telescope is directly relative to the diameter or aperture of the objective lens or primary mirror. The larger the lens or mirror, the further and larger the image produced.

TYPES OF... OPTICAL TELESCOPE

Learn all about the types of optical telescope used by amateur and professional astronomers alike

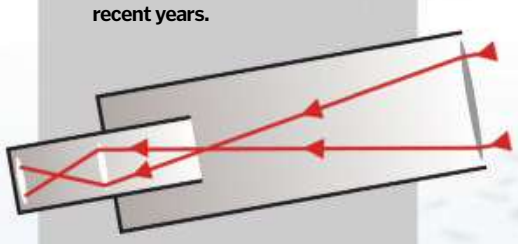
1 Reflecting

One of the most common types of optical telescope, a reflector utilises one curved mirror and one flat mirror to directly reflect light throughout its main body and form an image. The reflecting telescope was first created in the 17th century as an alternative to the refracting telescope, which at the time suffered from severe chromatic aberration – a failure to focus all colours at the same point.



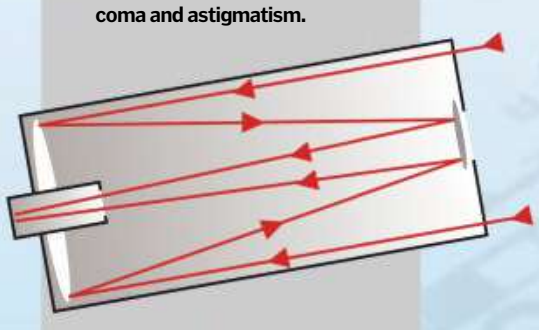
2 Refracting

The first type of telescope to be invented was a refractor. Utilising the partnership of a convex objective lens and a concave eyepiece lens to form its image, refractors are still used today. However, there are numerous technical considerations including lens sagging, chromatic aberration and spherical aberration that have demeaned their effectiveness in recent years.



3 Catadioptric

The most advanced and stable of all optical telescopes are catadioptrics, which employ a mixture of mirrors and lenses to form an image, as well as a number of correctors to maintain accuracy. The first catadioptric telescope was made by the optician Bernhard Schmidt, who with his patented Schmidt telescope corrected the optical errors of spherical aberration, coma and astigmatism.

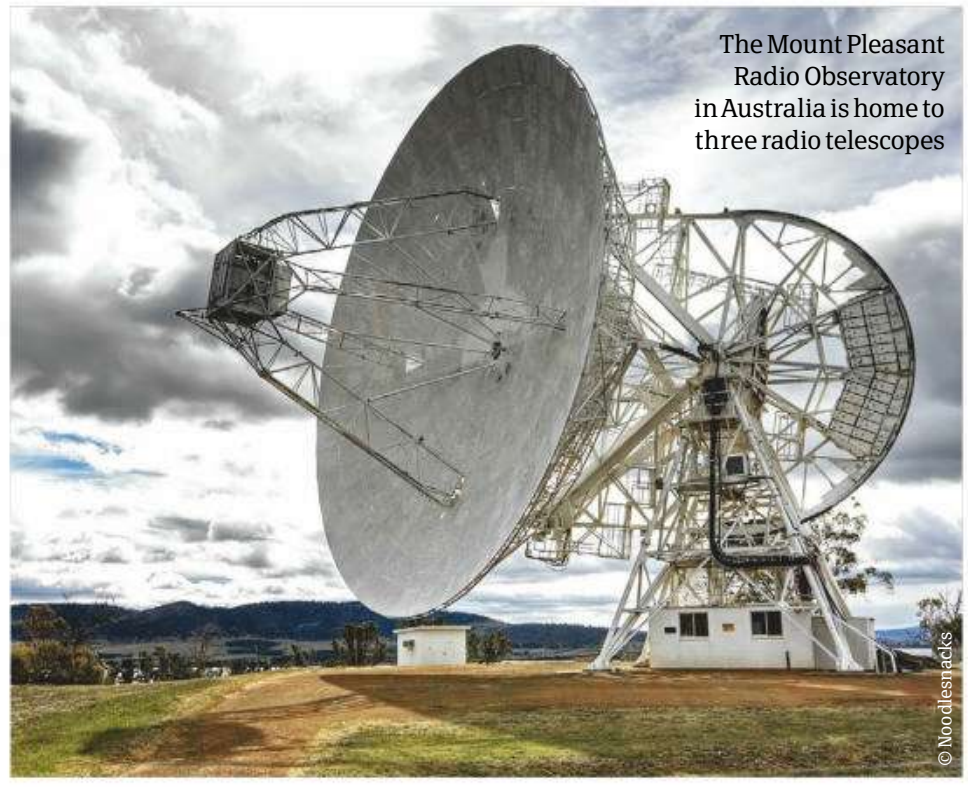


Radio telescopes

Usually characterised by their large dishes, radio telescopes allow us to receive signals from the depths of space

The radio telescope works by receiving and then amplifying radio signals produced from the naturally occurring emissions of distant stars, galaxies and quasars. The two basic components of a radio telescope are a large radio antenna and a sensitive radiometer, which between them reflect, direct and amplify incoming radio signals typically between wavelengths of ten metres and one millimetre to produce comprehensible information at an optical wavelength. Due to the weak power of these cosmic radio signals, as well as the range in wavelength that they operate in, radio telescopes need to be large in construction, as the efficiency of the antenna is crucial and can easily be distorted by terrestrial radio interference.

The most common radio telescope seen is the radio reflector: this consists of a parabolic antenna – the large visible dish – and operates in a similar manner to a television satellite dish, focusing incoming radiation onto a receiver for decoding. In this type of radio telescope, often the radio receiver and solid-state amplifiers are cryogenically cooled to reduce noise and interference, as well as having the parabolic surface of the telescope equatorially mounted with one axis parallel to the rotation axis of Earth. This equatorial mounting allows the telescope to follow a fixed position in the sky as Earth rotates, therefore allowing elongated periods of static, pinpoint observation. The largest filled-aperture radio telescope is the Five-hundred-meter Aperture Spherical Telescope (FAST), which is located in Guizhou, southwest China.



The Mount Pleasant Radio Observatory in Australia is home to three radio telescopes

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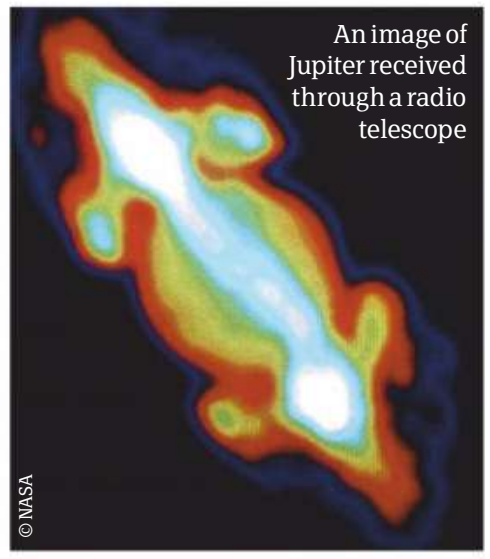

An image of Jupiter received through a radio telescope

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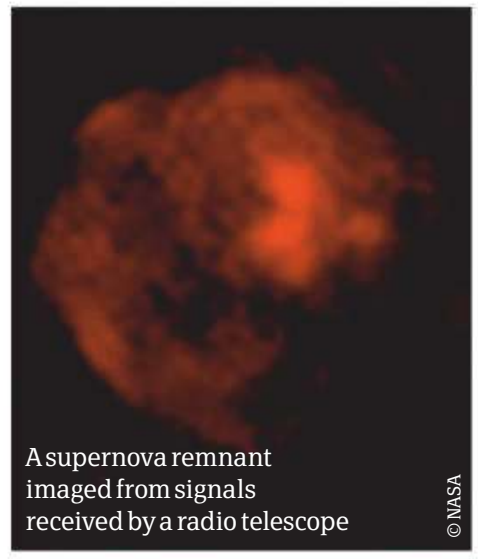

A supernova remnant imaged from signals received by a radio telescope

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1 Radio wave
Incoming radio waves are diverted towards the secondary reflector.

2 First focal room
An observation capsule located at the primary focus point.

3 Parabolic reflector
Dishes need to be large, as radio waves are weak and sporadic.

4 Receiver
Receivers need to be hypersensitive in order to capture signals.

5 Secondary reflector
The secondary reflector diverts radio waves down to the receiver.

6 Support structure
Radio telescopes tend to be made from light materials.

An artist's concept of the NuSTAR telescope with its 10 metre mast

The Rosette Nebula lies about 5,200 light years away and spans 130 light years across

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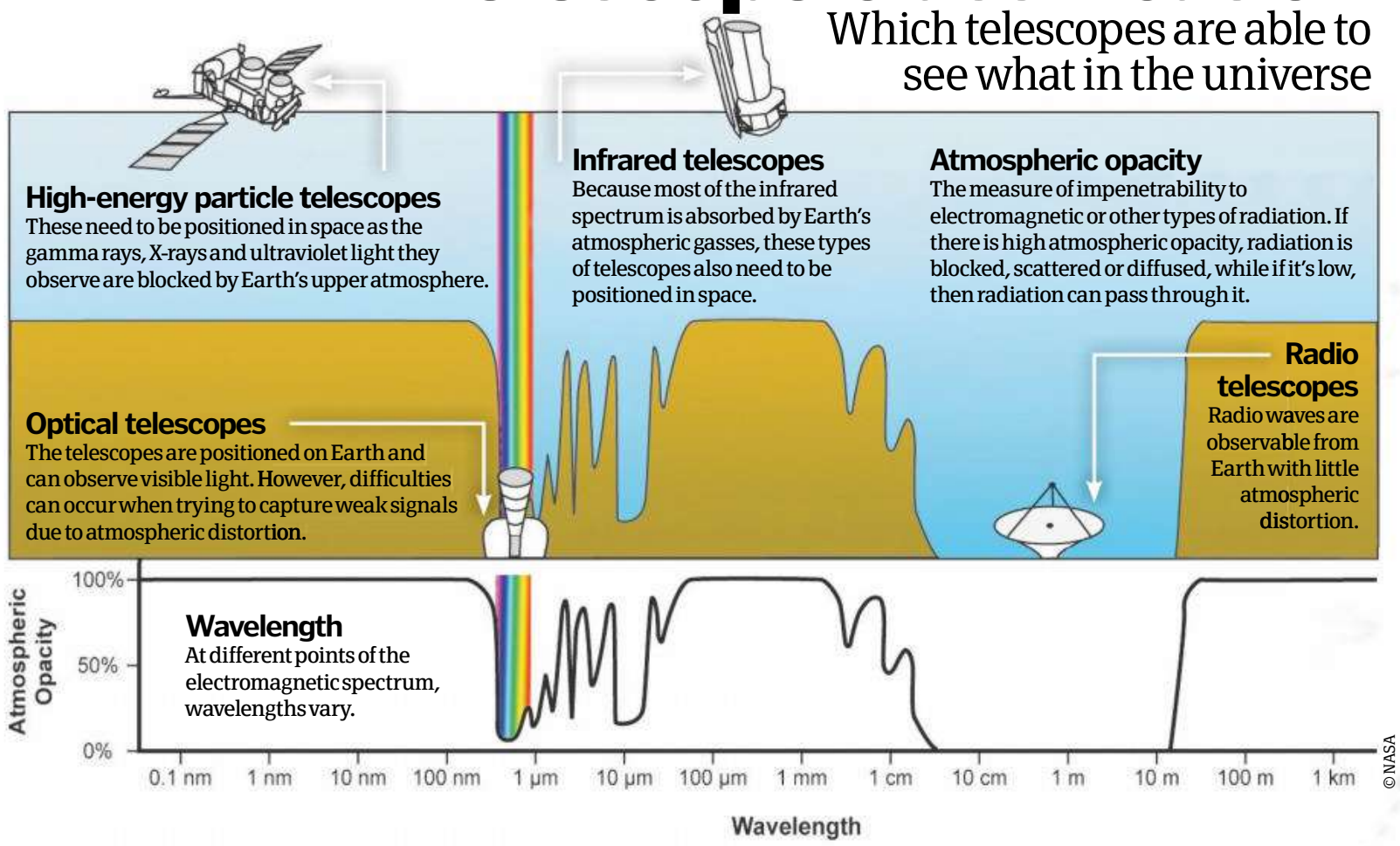
Telescope classification

Which telescopes are able to see what in the universe


High-energy particle telescopes
These need to be positioned in space as the gamma rays, X-rays and ultraviolet light they observe are blocked by Earth's upper atmosphere.
Infrared telescopes
Because most of the infrared spectrum is absorbed by Earth's atmospheric gasses, these types of telescopes also need to be positioned in space.
Atmospheric opacity
The measure of impenetrability to electromagnetic or other types of radiation. If there is high atmospheric opacity, radiation is blocked, scattered or diffused, while if it's low, then radiation can pass through it.
Optical telescopes
The telescopes are positioned on Earth and can observe visible light. However, difficulties can occur when trying to capture weak signals due to atmospheric distortion.
Radio telescopes
Radio waves are observable from Earth with little atmospheric distortion.
Wavelength
At different points of the electromagnetic spectrum, wavelengths vary.
Atmospheric Opacity
100%
50%
0%
0.1 nm
1 nm
10 nm
100 nm
1 µm
10 µm
100 µm
1 mm
1 cm
10 cm
1 m
10 m
100 m
1 km
Wavelength

© NASA

High-energy particle telescopes

Advanced technology is pushing back the boundaries of high-energy astronomy

The limits of radio and optical telescopes have led scientists in exciting new directions in order to capture and decode natural signals from distant galaxies. One of the most notable is the X-ray telescope, which differs in its construction thanks to the inability of mirrors to reflect X-ray radiation, a fundamental necessity in all reflection-based telescopes. In order to capture X-ray radiation, instead of being directly reflected into a hypersensitive receiver for amplification and decoding, it is acutely reflected a number of times, changing the course of the ray incrementally each time. To do this a telescope must be built from several nested cylinders with a parabolic or hyperbolic profile, guiding rays into the receiver.

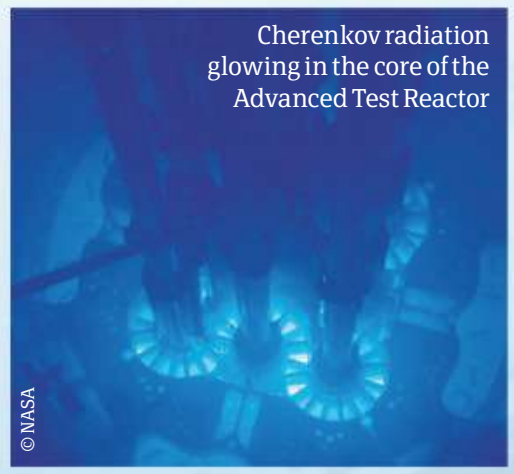
NASA's Chandra X-ray Observatory has been observing the cosmos for about 20 years

© NASA

Crucially, all X-ray telescopes must be operated outside of Earth's atmosphere, as it is opaque to X-rays. They must be mounted to high-altitude rockets or artificial satellites. Examples of orbiting X-ray telescopes include NASA's Chandra X-ray Observatory and NuSTAR, a Small Explorer mission.

Other high-energy particle telescopes include gamma-ray telescopes, which study the cosmos through the gamma rays emitted by stellar processes, and neutrino telescopes, which detect the electromagnetic radiation formed as incoming neutrinos create an electron or muon –an unstable subatomic particle – when coming into contact with water.

Because of this, neutrino telescopes tend to consist of submerged phototubes – a gas-filled tube especially sensitive to ultraviolet and electromagnetic light – in large underground chambers to reduce interference from cosmic rays. The phototubes act as a recording mechanism, storing any Cherenkov radiation emitted from the interaction of the neutrino with the electrons or nuclei of water. Then, using a mixture of timing and charge information from each of the phototubes, the interaction vertex, ring detection and type of neutrino can be detected.



Cherenkov radiation glowing in the core of the Advanced Test Reactor

© NASA

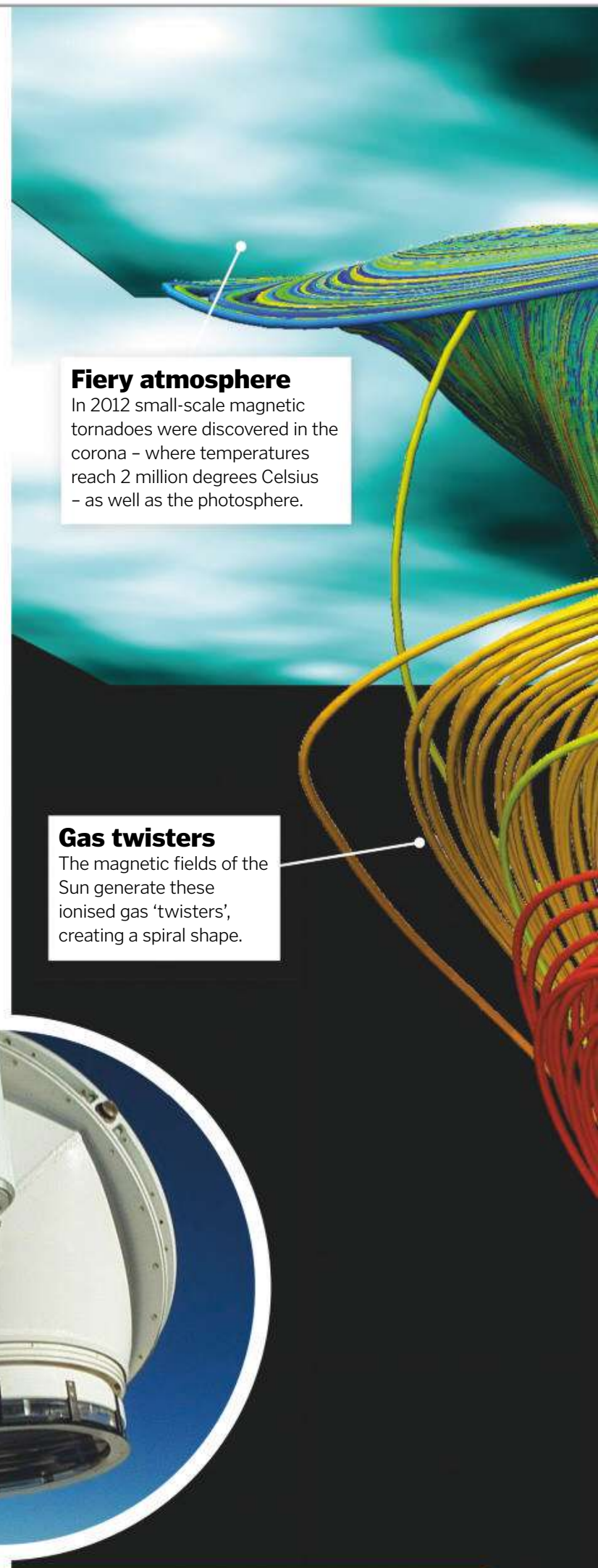
Solar tornadoes

The story behind twisters on the Sun that are a thousand-times larger than their Earth counterparts

A gigantic sphere of hydrogen plasma, or ionised gas, our Sun is by far the most dominant body in the Solar System, and one of its most visually intense events is a solar tornado. These enormous magnetic field anomalies are between 100 and 1,000 times larger than what we're used to on Earth and have been observed at a gigantic 100,000 kilometres tall. It has been calculated that over 11,000 of these phenomena are on the Sun's surface at any time. They are believed to be a potential source of heating for the outer reaches of the Sun and could even contribute to aurorae on our planet.

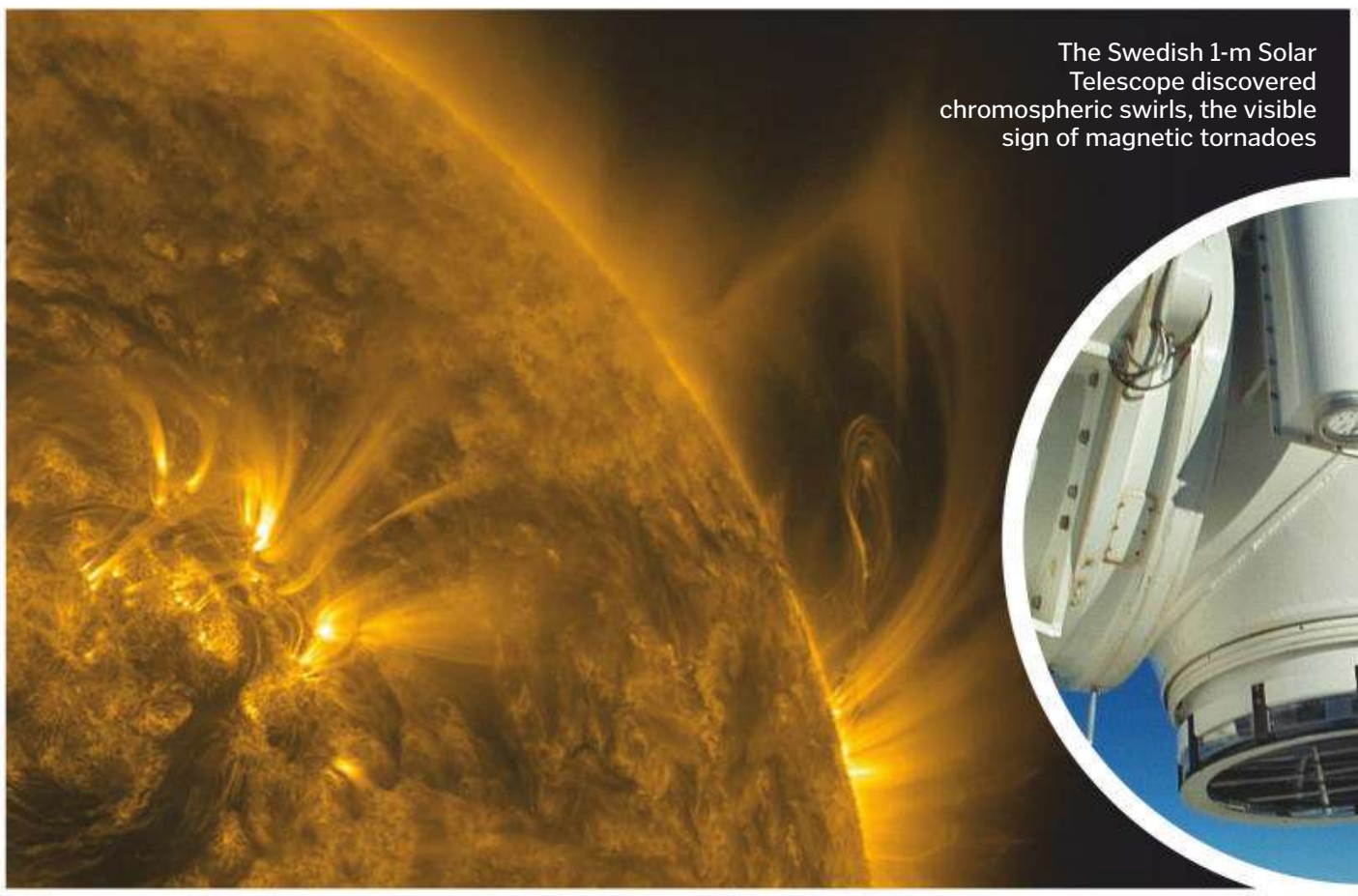
Solar tornadoes differ from Earth-based twisters because they are comprised of a magnetic field of plasma. They are more frequently spotted around the Sun's equator and poles, as this is where magnetism is most prominent. They exist on other stars as well as the Sun and burn at over a million degrees Celsius. They don't twist like terrestrial tornadoes do and remain fixed in place.

They appear in clusters, and their main function seems to be to heat their star's outer atmosphere by moving energy from the surface to the uppermost layer, the corona. They generate 100 to 300 watts per square metre and are believed to be the reason for the corona's heat production, which has puzzled scientists and astronomers for generations. Observations from the Swedish 1-m Solar Telescope in 2008 have increased our understanding of how nature heats magnetised plasma and how the 'chromospheric swirls' we can see are a result of the tornadoes.



Fiery atmosphere
In 2012 small-scale magnetic tornadoes were discovered in the corona – where temperatures reach 2 million degrees Celsius – as well as the photosphere.

Gas twisters
The magnetic fields of the Sun generate these ionised gas 'twisters', creating a spiral shape.



The Swedish 1-m Solar Telescope discovered chromospheric swirls, the visible sign of magnetic tornadoes

Why is the corona so hot?

A curious anomaly of our host star is the fact that the corona, an aura of plasma surrounding it, is much hotter than many other areas of the Sun closer to its core. The corona can reach about 2 million degrees Celsius, while on the surface it is a measly – by comparison – 5,500 degrees Celsius.

Scientists and astronomers have long been perplexed by this, but some new theories might explain why. Recent notions reason that heat is injected into the corona by wave heating from the core.

As the corona is dominated by magnetic fields that are constantly connecting and engaging with each other, a convection zone is created, which releases high amounts of energy and heat. Solar tornadoes are linked to the plasma's astonishing heat levels as it contributes to coronal mass ejections (CME) and the solar wind in the Sun's atmosphere. To discover more, NASA has launched a mission known as the Parker Solar Probe, which took off for the Sun in 2018.

Solar power
This illustration is a giant solar tornado rather than a smaller chromospheric swirl. These swirls were only discovered in 2008 and had only been observed in the photosphere.

Far-reaching
This twister extends all the way through the Sun's atmospheric layers – from the convection zone to the outer reaches of the corona.

Spiralling out of control
Like on Earth, solar tornadoes have a narrow funnel at the bottom which widens as it rises.

A solar storm chaser

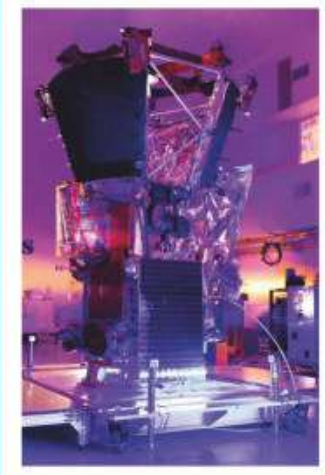
Dr Sven Wedemeyer-Böhm from the Institute of Theoretical Astrophysics

How similar are solar tornadoes to tornadoes on Earth?
Aside from the visible appearance, tornadoes on Earth and on the Sun are very different phenomena. In both cases the tornado funnel is narrow at the bottom and widens with height in the atmosphere. Particles inside tornadoes are forced to move in spirals. Tornadoes on Earth occur as a result of temperature and gas pressure differences and strong shear winds. Solar tornadoes are generated by rotating magnetic field structures, which force the plasma, the ionised gas, to move in spirals.

How do solar tornadoes contribute to aurorae on Earth?
It has been speculated that giant tornadoes may serve as a possible trigger of solar eruptions, where they build up a magnetic field structure until it destabilises and erupts. As a consequence, ionised gas could get ejected towards Earth, which would then contribute to aurorae. However, as of now there's no direct connection confirmed.

Will any missions investigate this phenomenon further?
There are missions such as Solar Orbiter and the planned Solar-C. There will also be some major progress with ground-based observatories with the Daniel K. Inouye Solar Telescope (DKIST) – formerly the Advanced Technology Solar Telescope, or ATST – which is currently built on Hawaii, and possibly the four-metre European Solar Telescope (EST), which may be built in the future. These new instruments will allow for an even closer look at our Sun and will enable us to answer the many open questions that we still have about solar tornadoes.

What is the primary difference between giant solar tornadoes and small-scale magnetic tornadoes?
It is currently not clear if these are different phenomena or not. Small-scale magnetic tornadoes have only been observed from the top so far, such as in the middle of the solar disc, whereas giant tornadoes are seen more towards the limb of the Sun, in other words from the side. In general magnetic tornadoes tend to have somewhat smaller diameters than giant tornadoes, but it is too early to draw solid conclusions.



NASA's Parker Solar Probe will give us a better understanding of solar tornadoes

© SST/ISP; Wedemeyer-Böhm et a ; NASA/SDO

Binary stars explained

How do multi-star systems form – and do planets exist where the sun sets twice?

It is estimated that a third of the stars in the Milky Way are part of a binary (two) or multiple (three and upwards) star system, with more than one star orbiting a common centre of mass, or barycentre.

Depending on the mass of each star and the conditions of their formation, they can be quite close together or millions of miles apart, and the time it takes for them to orbit varies from hours to millennia. Binary star systems are particularly useful to astronomers because they can accurately determine the mass of the stars by analysing their orbits; this then enables them to estimate the mass of similarly bright lone stars.

Some binaries can be seen through a telescope, but many are only detected indirectly, either when one star eclipses another or when the wavelengths of light emitted vary as the stars circle around their shared barycentre.

If the stars are close enough together their gravitational pull enables them to exchange matter; this can be seen as a bright disc around the recipient star. If the recipient is a white dwarf, hydrogen received from its companion can be compressed by the intense gravity at the core and undergo nuclear fusion. This process releases huge amounts of energy, which can be seen as a nova. In some cases the energy can be so great that it triggers a supernova event, destroying the star.

Binary star systems can also drift apart, resulting in the formation of single stars. The break-up of multi-star systems can also occur due to close interaction with neighbouring celestial bodies, causing dramatic fluctuations in gravitational pull and leading to stars being thrown out of a system. These 'runaway stars' have been seen hurtling through space at speeds of thousands of kilometres per second.

A planet with two sunsets

Around 200 light years away, Kepler-16b orbits two stars in the constellation of Cygnus

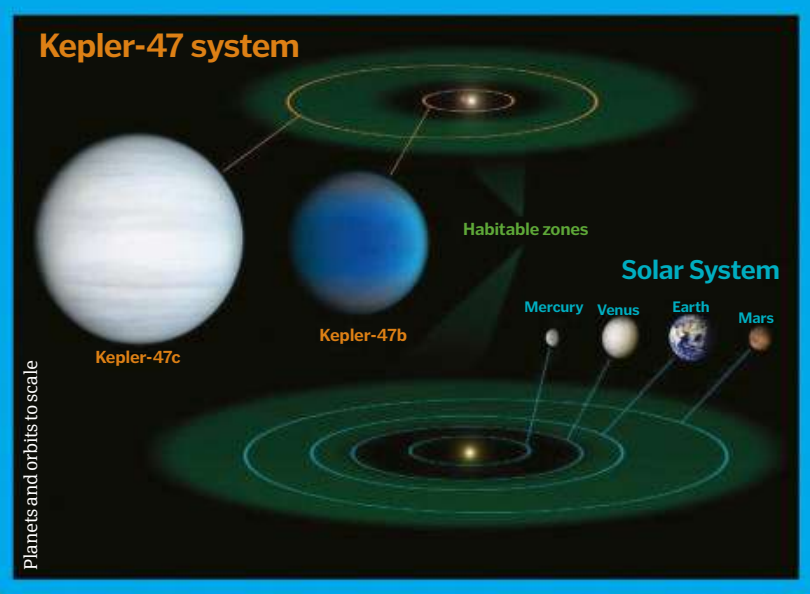
Kepler-16A
The larger of the two stars is an orange dwarf, 69 per cent the mass of our Sun.

Kepler-16B
The smaller star is just 20 per cent the mass of our Sun and is a cooler red dwarf.

Kepler-16b
This planet is half gas and half rock and ice, with surface temperatures between -101 and -73 degrees Celsius.

Living under two suns

Planets in binary star systems can orbit one or both of the stars. The surface temperature of some of these bodies varies wildly as the distance to the stars changes when they orbit. However, it is now thought that binary star systems may be more likely to contain extraterrestrial life than single star systems like our own. For planets to be at the correct temperature for life in solitary star systems they have to be quite close to their star, which leaves them open to bombardment by solar wind and harmful radiation. However, if two low-mass stars are close together, planets farther out will be able to get enough heat without being subjected to so much damage. There are so many binary star systems that, if you subscribe to this theory, then the chances of finding planets in a habitable zone with similar environmental conditions to our own – and thus life – are greatly increased.



Double star origins

All stars are the product of dust and gas collapsing under gravitational force. As the collapse occurs the material is not always uniformly distributed, creating areas of denser matter which pull the dust into spinning discs, gradually incorporating it into two or more separate protostars. It is also possible for stars to 'capture' other stars as they pass each other in space, but their gravitational attraction is rarely strong enough. Capture is a viable option for the formation of multi-star systems, which have much greater combined gravitational pull, but currently it is thought to be a secondary method.

A supercomputer simulation recreating the birth of a binary system with two protostars (shown in white) accreting from a swirling cloud of dust and gas (orange)

© NASA; SPL

Eclipse

As the stars move in front of one another, the light intensity seen from Earth alters, allowing astronomers to calculate their distance and mass.

The statistics...

Hybrid Hydrogen Rapide S

Manufacturer:
Aston Martin/Alset Global

Dimensions:
Length: 5,019mm
Width: 2,140mm
Height: 1,360mm

Weight: 1,990kg (4,387lbs)

Top speed:
306kph (190mph) on petrol

Power: 560bhp (418kW)

Engine:
V12, alloy, 48 valve, 5,935cc

Inside a hydrogen hybrid supercar

You may not think eco-friendly and speed go together, but Aston Martin's Rapide S hybrid proves otherwise

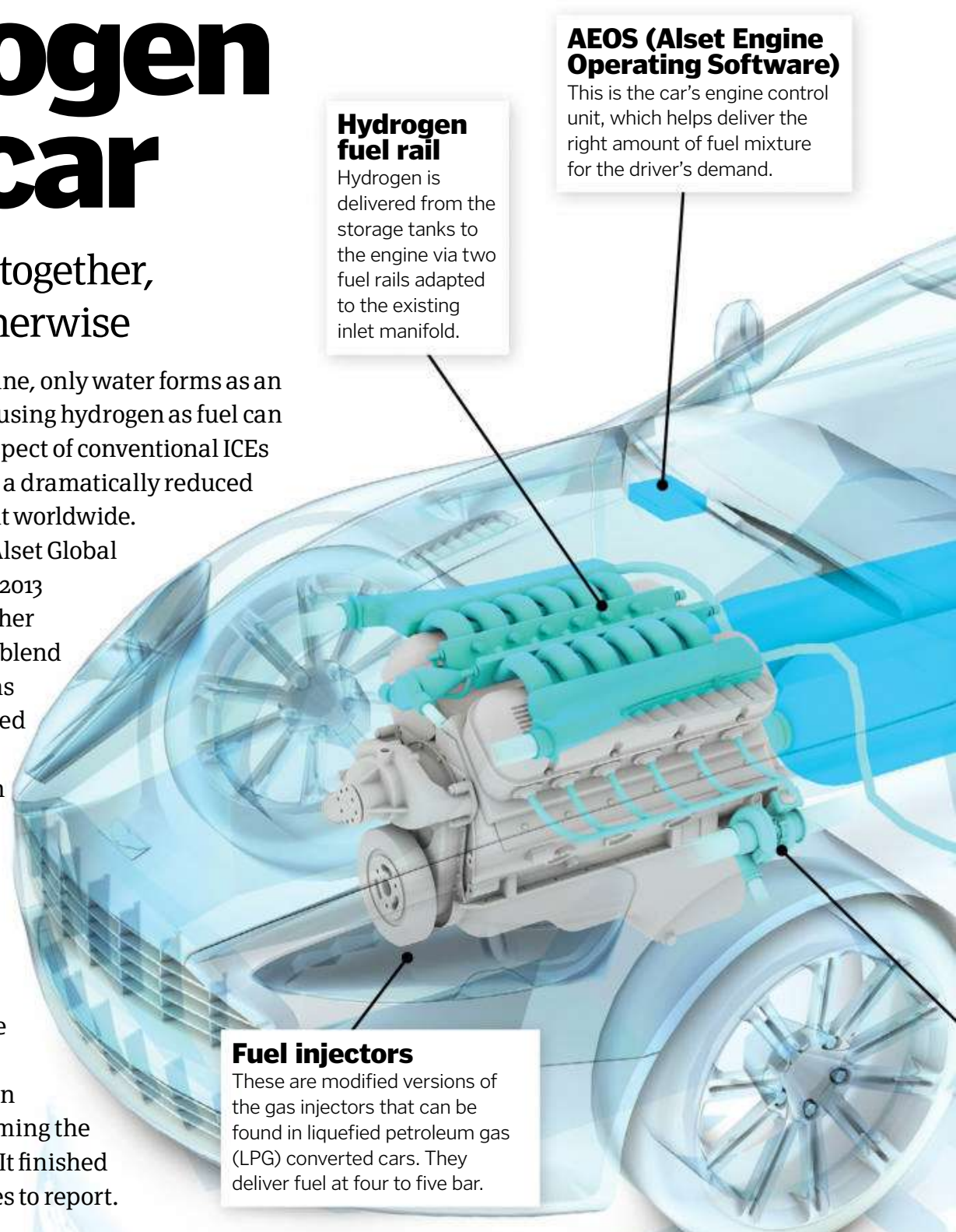
The Hybrid Hydrogen Rapide S made history at the Nürburgring 24-hour race in May 2013. It was the first hydrogen hybrid supercar to compete, and the first to run a zero carbon dioxide emissions lap.

You may have heard of hydrogen technology in cars before, such as the Honda FCX Clarity. However, there is no fuel cell involved here. Instead, the hydrogen is burned in the conventional Aston Martin six-litre V12 engine to produce its power. So what are the differences between burning hydrogen and petrol in an internal combustion engine (ICE)?

In a conventional ICE, petrol – or more specifically octane – is burned in air to produce the engine's power via this simplified equation: $2C_8H_{18} + 25O_2 \rightarrow 16CO_2 + 18H_2O$.

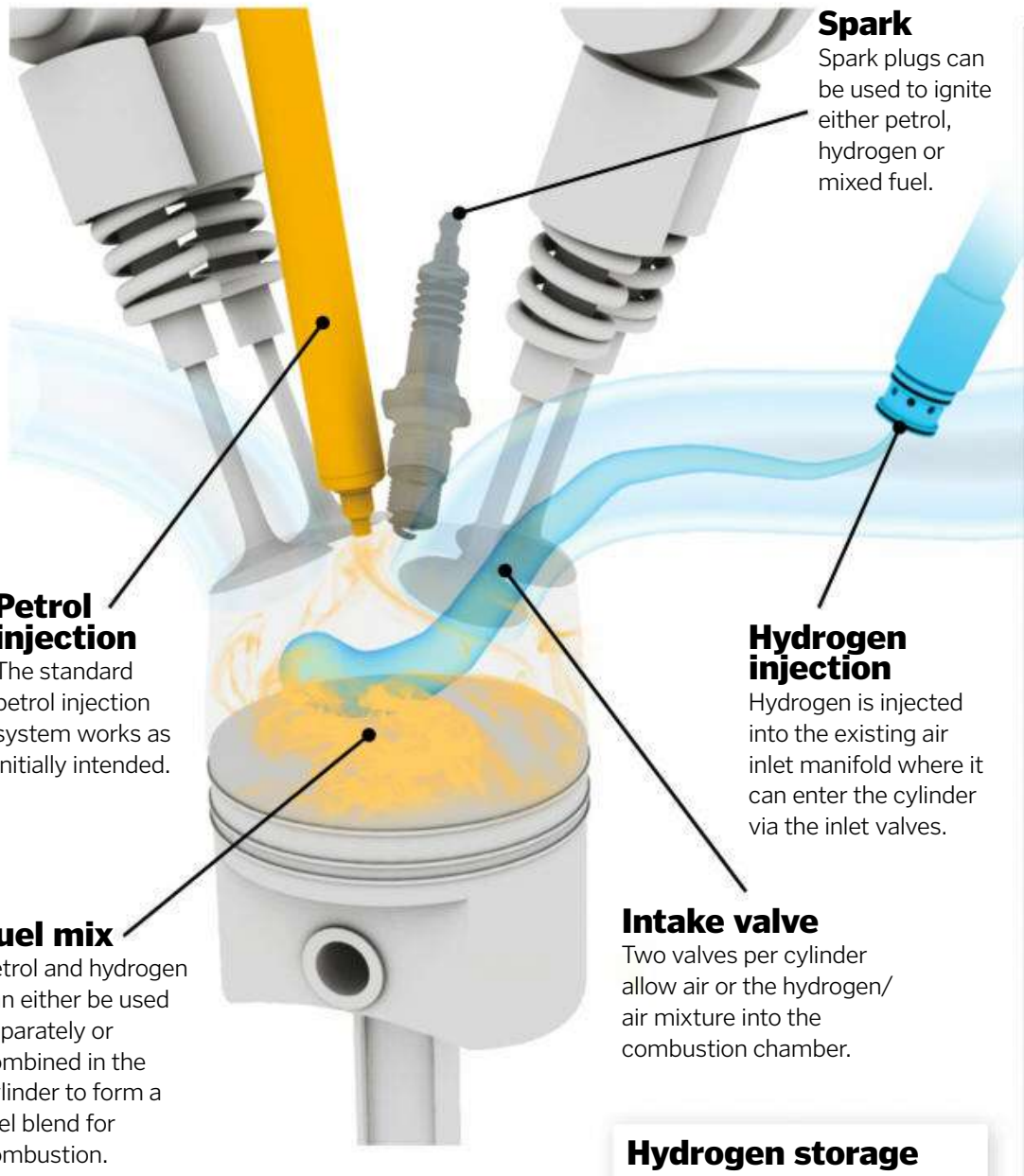
The products of the reaction are a bunch of carbon dioxide molecules and water vapour. This carbon dioxide is a significant contributor to global warming, and increasing efforts to reduce these emissions are underway. But if you use hydrogen as the fuel in an ICE, you get a very different outcome: $2H_2 + O_2 \rightarrow 2H_2O$. If pure hydrogen and oxygen from the air are combusted in an engine, only water forms as an emission. Therefore, using hydrogen as fuel can remove the carbon aspect of conventional ICEs altogether, leading to a dramatically reduced carbon dioxide output worldwide.

Aston Martin and Alset Global teamed up to adapt a 2013 Rapide S to run on either petrol, hydrogen or a blend of the two. The car was tested on the renowned 'Green Hell' of the Nürburgring by Aston Martin's then-CEO Ulrich Bez in 2013 in preparation for its appearance at the Nürburgring 24-hour race in May of the same year. During the race it successfully completed a full lap on pure hydrogen, becoming the first ever car to do so. It finished the race with no issues to report.


AEOS (Alset Engine Operating Software)
This is the car's engine control unit, which helps deliver the right amount of fuel mixture for the driver's demand.
Hydrogen fuel rail
Hydrogen is delivered from the storage tanks to the engine via two fuel rails adapted to the existing inlet manifold.
Fuel injectors
These are modified versions of the gas injectors that can be found in liquefied petroleum gas (LPG) converted cars. They deliver fuel at four to five bar.

Hydrogen injection

The injection system was designed to require as little remodelling and new parts to the existing engine as possible. It is inherently simple: compressed gaseous hydrogen is released from the storage tanks at around four to five bar and is fed into the inlet manifold of the existing six-litre V12. This is usually the path that air takes to get to the engine, where it is mixed with petrol. This adaptation allows hydrogen to be injected with the air to reach the combustion chamber. The rate of gas flow is determined by Alset Global's own engine management software, which also controls the fuel mix ratio.



Spark
Spark plugs can be used to ignite either petrol, hydrogen or mixed fuel.

Petrol injection
The standard petrol injection system works as initially intended.

Hydrogen injection
Hydrogen is injected into the existing air inlet manifold where it can enter the cylinder via the inlet valves.

Fuel mix
Petrol and hydrogen can either be used separately or combined in the cylinder to form a fuel blend for combustion.

Intake valve
Two valves per cylinder allow air or the hydrogen/air mixture into the combustion chamber.

Hydrogen storage
3.2 kilograms of gas is compressed to 350 bar and stored in aluminium-lined carbon-fibre skinned tanks.

Supply pipe
The hydrogen is fed from the storage tanks via stainless steel piping at up to five bar.

Race ready
The four-door Rapide S was fully stripped and prepared for racing with a rollcage and safety cutoffs to meet race standards.

Twin turbochargers
These are used to help make up for the performance losses when using hydrogen as a fuel by forcing more air and fuel into the engine.

Rapide S hybrid under the hood

See how Alset Global modified the existing four-door supercar to run on hydrogen

Behind the Hybrid Hydrogen project

Thomas Korn was vice president of product management and technology at Aslet Global when the Hybrid Hydrogen Rapid S was being developed

Can you tell us the main difficulties you faced using this system?
The main challenges were combustion control and power loss mitigation. Our focus in the past has been to improve the two, and develop technologies for that. A very challenging aspect was that because it was a new engine, implementing the hydrogen technologies into it in a tight timeframe was also a [big hurdle].

Was there a significant drop in power output when using hydrogen?
If you use hydrogen as a fuel with a lower volumetric energy density, you always lose power. We used two different processes that enabled us to reach 90 per cent of the performance an engine would normally have using gasoline, one of which was using two turbochargers to increase the mixture value in the combustion chamber. Secondly, we used a blend of fuels, which allows us to control combustion and gain more power.

How reliable is the technology?
We think we have shown that even in such demanding and harsh conditions the technology is very reliable. The technology can be implemented relatively quickly in a commercial context.

Finally, what is the top speed of the Hybrid Hydrogen Rapide S?
For the race we were limited to a certain power output by the race organisations. Using gasoline we reached 560 horsepower, and with pure hydrogen we were just below that. We had to use an air restrictor in gasoline mode to bring the engine power down. For the maximum speed, the weight, aerodynamics and the track layout dictate this. We achieved 280 kilometres [174 miles] per hour on the course in gasoline mode and we were not much lower than that [in hydrogen mode].

On board a cargo plane

How do freight aircraft differ from passenger planes, enabling them to transport much greater loads all over the planet?

Cargo planes – whether used in the private, military or commercial sphere – are fixed-wing vehicles that have usually been designed with haulage in mind or have been converted from standard aircraft. Passenger planes commonly have a specialised hold that can store around 150 cubic metres (over 5,000 cubic feet) of freight, found on the underside of the craft. Dedicated freight planes don't need the seats or any of the other amenities on commercial flights – that said, their design amounts to much more than a hollowed-out passenger plane.

To make the most efficient use of the space available, the floor is lined with a walkway and electronic rollers that allow prepackaged pallets to be rolled back as far as possible, without the need for a forklift. Large cargo bay doors are installed to fit bigger items through and, in some examples, like the Boeing 747-400, the nose lifts up to allow particularly large items to pass down the body of the plane. With the demands of air freight ever increasing, aircraft with huge cargo capacities like the Airbus A300-600 Super Transporter (also known as the Beluga), are becoming the norm.

It's not enough just to increase the size of the aircraft hold though. In order for a cargo plane to efficiently and safely transport its mighty load, a number of adaptations must be made to the overall avian design. For example, the wings and tail are built high to allow the freight to sit near the ground and to facilitate loading; the fuselage is much bigger; and – similar to heavy goods vehicles – cargo planes typically feature a larger number of wheels to support their weight on landing.

"The wings and tail are built high to allow the freight to sit near the ground and to facilitate loading"

Plane politics

The Xian Y-20 is a military long-range transport plane that's still in development by China, although it has recently been filmed on a short test flight. It's a similar class of aircraft as Russia's Ilyushin Il-76 or the US Boeing C-17, and though China maintains a tighter guard over its military secrets than most, it has an estimated payload in the region of 72,000 kilograms (160,000 pounds) – that's quite a bit, by any country's standards! The PLAFF (People's Liberation Army Air Force), or avian branch of the Chinese military, had long favoured the development of fighter jets over this kind of support aircraft, so that the Y-20 project was sidelined when it started in 2005. However, following the Sichuan earthquake of 2008, China was unable to effectively drop relief supplies with its small fleet of cargo planes, so the US had to assist with two C-17s. This embarrassment undoubtedly spurred the Chinese government into pushing on with the Y-20's development.

Cargo plane credentials

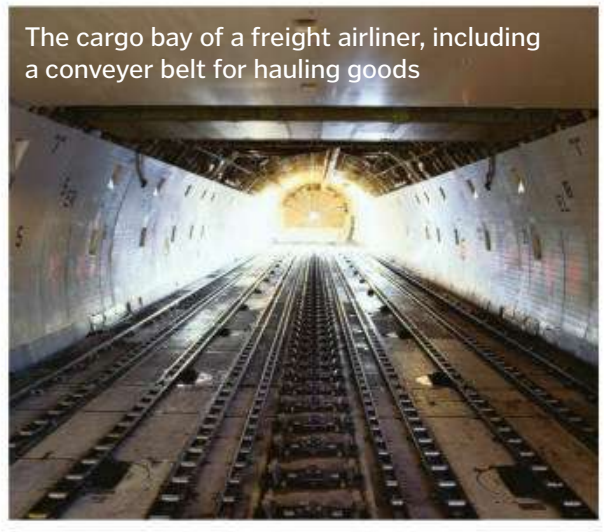
HIW pinpoints what a military cargo transporter needs to get the job done

Engine
Four turbofan jet engines can provide as much as 19,504kgf (43,000lbf) of thrust.

Vehicle ramp
Large aircraft (like Lockheed's C-5 Galaxy) are quite capable of carrying several light vehicles which can be driven on via ramps.

Lightening the load

Depending on the type of cargo being carried (very large items or military vehicles may be exceptions), many cargo planes will use ULDs, or unit load devices. These allow the crew to prepackage cargo into single units that can more easily be loaded into the hold prior to the flight, saving a great deal of time. It's a similar system to that used in shipping, maximising the space used at the same time and, thus, increasing efficiency (and profits). The ULDs themselves are either robust and lightweight aluminium pallets or aluminium-floored containers with toughened plastic walls. The containers are sometimes converted into self-contained refrigeration units to store perishable goods.



The cargo bay of a freight airliner, including a conveyer belt for hauling goods

Lockheed Martin's C-5 Galaxy has 12 internal wing tanks with a total capacity of 194,370l of fuel

Cargo doors
Both fore and aft of the aircraft feature cargo bay doors, with the nose cone lifting at the front to allow access.

Landing gear
More cargo means more weight, so more wheels and a greater landing distance are required.

Cargo bay
A 37m (121ft) cavity can hold about 880m3 (31,000ft3) of cargo weighing up to 67 tons.

Passengers
On big military craft, an upper deck carries several dozen personnel as well.

Cockpit
Military cargo planes are usually manned by several crew including the commander, pilot and loadmasters.

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HOW INTEGRATED CIRCUITS WORK

Found in every electronic device you own, the integrated circuit is absolutely fundamental in the modern world

When the greatest inventions of the 20th century are weighed up for their merits there are few people who think of the integrated circuit. They often name some of the devices which it has enabled – which isn't difficult, as they are numerous – but rarely do we celebrate the bundle of transistors that was first crudely assembled in 1958.

In many ways that is totally understandable. The integrated circuit is by its very small – or in a more modern and accurate context, nanoscale – nature largely unimpressive. It's essentially a handful of metal and semiconductor components strapped together to perform invisible functions. But it is through these circuits that all modern electrical devices operate, with everything from personal computers through to smartphones and televisions relying on them to perform all number of essential processes.

An integrated circuit is an assembly of miniaturised active and passive devices; active examples include transistors and diodes, while passive examples include capacitors and resistors. Together they are built up on a thin substrate of semiconductor material such as silicon – which is where the US' chip-making region Silicon Valley gets its name.

Combined these structures create a computer chip, which typically range from a few millimetres up to a few centimetres – such as with CPUs – in size. These chips protect their numerous internal integrated circuits with plastic shells and are combined to create the super-powerful electronic devices many of us couldn't live without today.

In this feature **How It Works** takes a closer look at the science, manufacturing processes and history of the tiny integrated circuit, charting its development over 60-plus years and contemplating what integrated circuits may have in store for the future.

Integrated circuits

Follow some of the key milestones in the development of the integrated circuit

1947

The point-contact transistor is invented at Bell Labs. The p-n junction transistor is created the following year.

1952

British electronics engineer Geoffrey Dummer (right) conceives the integrated circuit. He builds a prototype and presents it at a conference in Washington DC.

1958

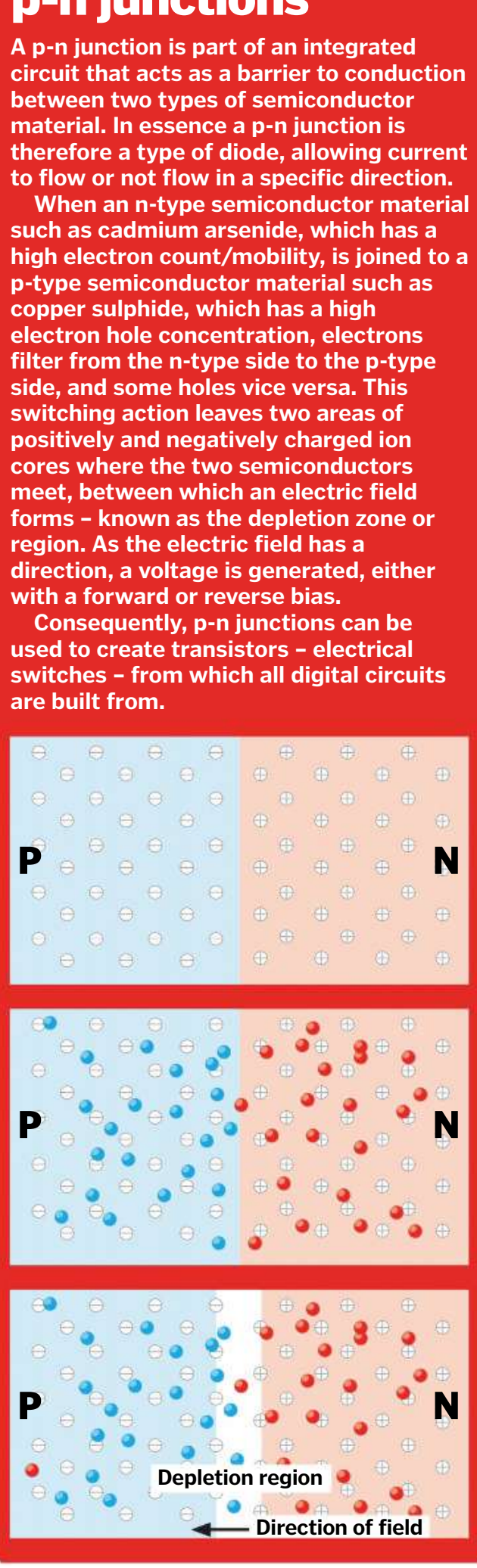
The first proper integrated circuit is built by Jack Kilby at Texas Instruments. It features a transistor, several resistors and a capacitor.

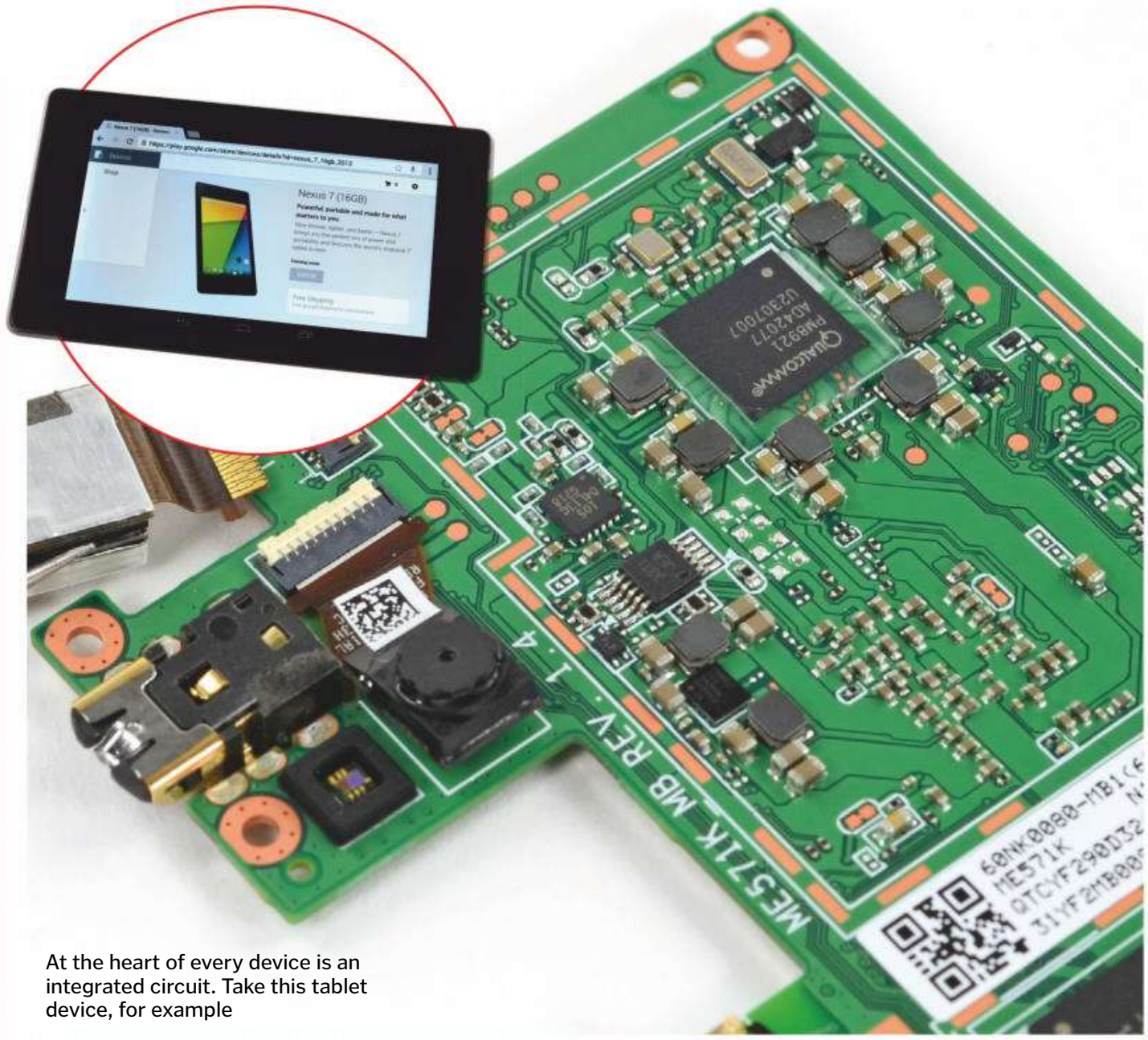
Understanding p-n junctions

A p-n junction is part of an integrated circuit that acts as a barrier to conduction between two types of semiconductor material. In essence a p-n junction is therefore a type of diode, allowing current to flow or not flow in a specific direction.

When an n-type semiconductor material such as cadmium arsenide, which has a high electron count/mobility, is joined to a p-type semiconductor material such as copper sulphide, which has a high electron hole concentration, electrons filter from the n-type side to the p-type side, and some holes vice versa. This switching action leaves two areas of positively and negatively charged ion cores where the two semiconductors meet, between which an electric field forms – known as the depletion zone or region. As the electric field has a direction, a voltage is generated, either with a forward or reverse bias.

Consequently, p-n junctions can be used to create transistors – electrical switches – from which all digital circuits are built from.





At the heart of every device is an integrated circuit. Take this tablet device, for example

Analogue vs digital

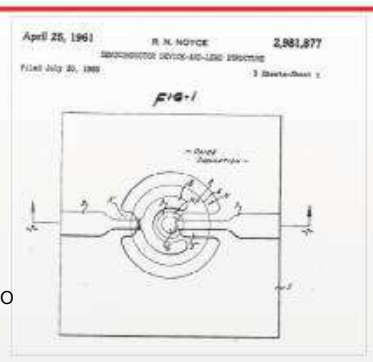
There are two basic types of integrated circuit: analogue and digital. Analogue, or linear circuits are the most basic and are used typically in electronic devices that collect or send signals, such as microphones. In this example, an analogue circuit is used to modify the incoming microphone signal, such as amplifying it, and improving the audio projection.

In contrast, digital circuits – which are common in electronic devices like computers and smartphones – are more complicated. These integrated circuits operate in a binary on/off way, which according to Boolean algebra – logic rules – allows for a series of different functions.

It is by combining multiple digital integrated circuits together that modern microprocessors are built, with the processors' clock frequency determining the speed at which various functions are performed.

1959

Robert Noyce invents a more practical silicon integrated circuit. He is granted a patent for it two years later.



1961

Commercial, mass-produced integrated circuits begin to be sold by Silicon Valley industry founder, Fairchild Semiconductor.

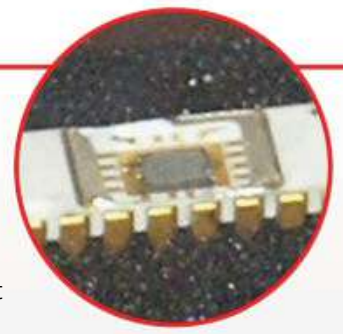
FAIRCHILD SEMICONDUCTOR®

1965

Electrical engineer Gordon Moore predicts that the integrated circuit density-to-dollar ratio will double every year.

1971

After being founded in 1968, Intel goes on to produce the Intel 4004, the world's first microprocessor. The processor runs at 108KHz and has 2,300 transistors.



Circuitry up close

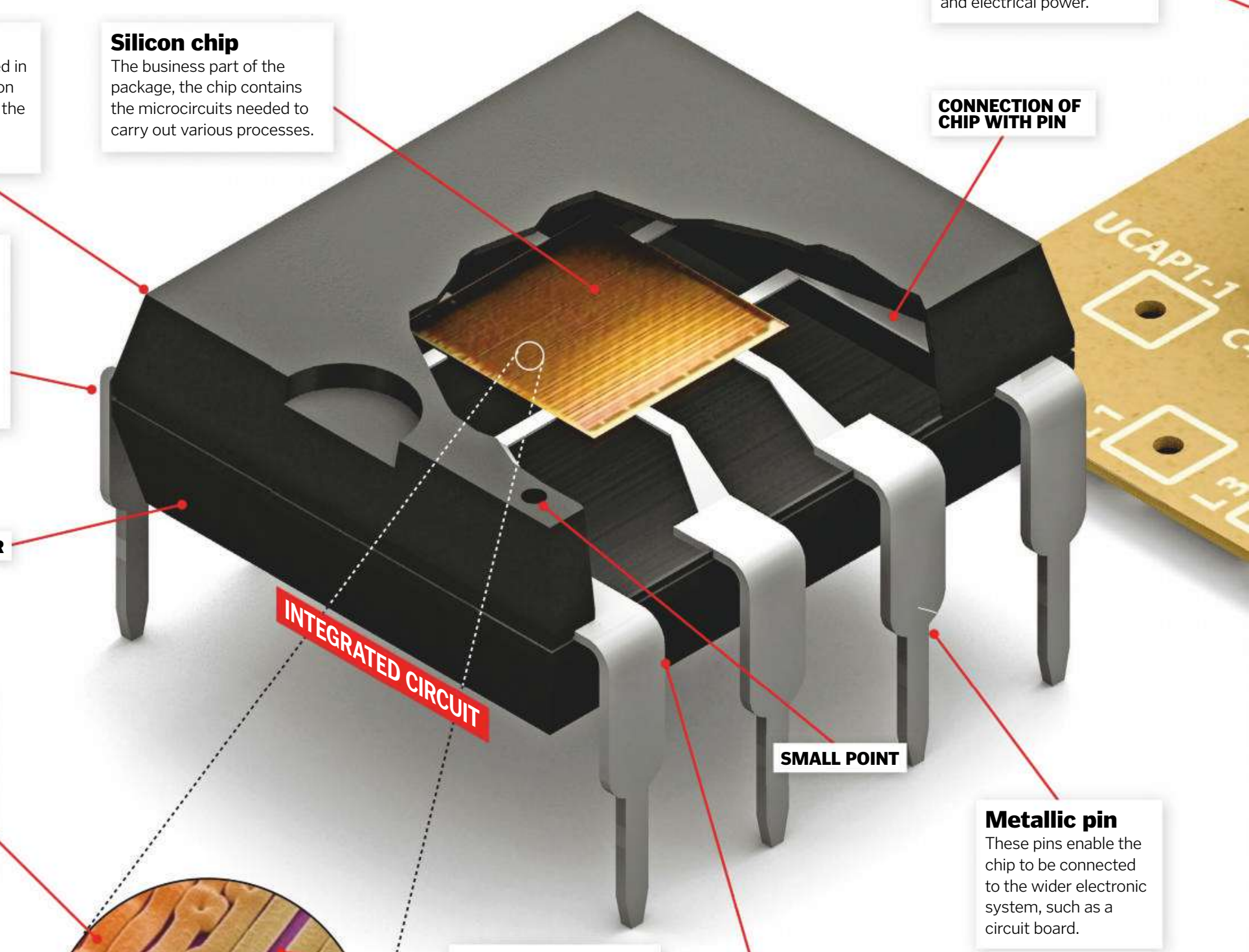
We take a look at the nanoscale tech that distinguishes integrated and discrete circuits

All in one
Generally chips are encased in the substrate and protection structures, which connect the chip to the rest of the electronic components.

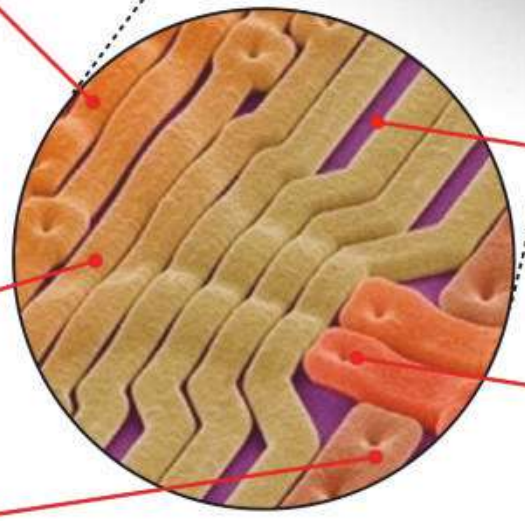
Silicon chip
The business part of the package, the chip contains the microcircuits needed to carry out various processes.

Transistor
A semiconductor device capable of amplifying and switching electronic signals and electrical power.

What are they used for?
The integrated circuit has a wide variety of functions: oscillators, amplifiers and flash memories are just a few examples of applications.



Under the microscope
In order to discover the chip structure, it should be viewed with a powerful magnifying glass or directly under a microscope.



Microcircuits
Made up of thousands of tracks, microcircuits determine the movement of currents within the microprocessor.

TRACKS

Substrate
Works as a base and an insulator of the microprocessor's circuits.

Connection points
These indicate where the circuits are connected to the components located on the opposite side of the substrate via tracks.

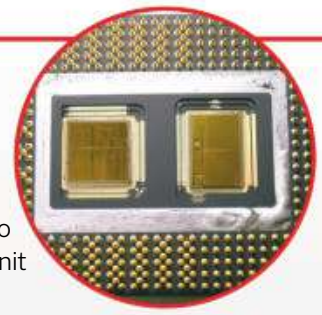
Integrated circuit
The electronic integrated circuit, which replaced the discrete one, contains all components in one piece and it is manufactured and connected all in the same process.

Metallic pin
These pins enable the chip to be connected to the wider electronic system, such as a circuit board.

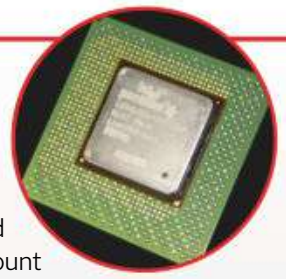
1981
Very large-scale integration processes are introduced, with circuits exceeding 100,000 transistors.

1989
Intel releases its hugely popular i486 microprocessor unit, which has a commercial record of 1.2 million transistors.

1995
Intel's Pentium Pro microprocessor unit launches, packed with 5.5 million transistors.



2000
Intel takes speed and transistor count to a whole new level with its Intel Pentium 4 CPU, boasting 42 million transistors.

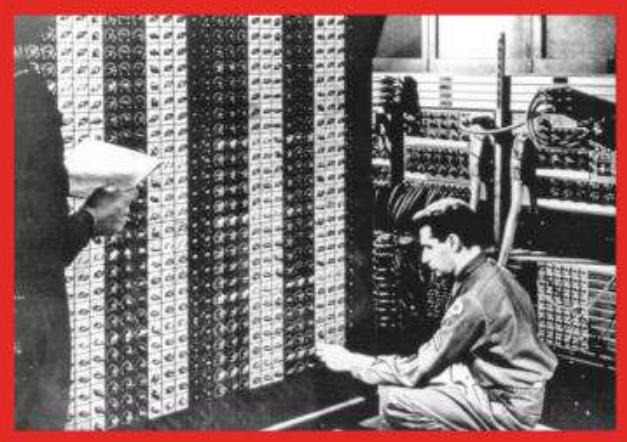


Capacitor
Capacitors are passive two-terminal components – made from a series of conductors and insulators – that hold energy electrostatically.

What came before the integrated circuit?

The famous Electronic Numerical Integrator and Computer (ENIAC) is the perfect example of the period before the integrated circuit.

Built in the US between 1943 and 1945 to calculate the trajectories of projectiles, this machine of 27 tonnes could solve 5,000 additions in one second, thanks to its 18,000 vacuum tubes. Today, a microchip that fits on the tip of your finger far exceeds this ability.



Discrete circuit
Discrete circuits are those where the components are encapsulated in themselves and welded onto a substrate.

Resistor
Resistors are passive two-terminal components that implement electrical resistance, limiting the flow of current in a circuit.

PLATE

DISCRETE CIRCUIT

A circuit in the making

1 Draw circuit
Integrated circuit design is drawn onto paper.

2 Photolithography
With a photolithography process the design is copied onto a silicon wafer.

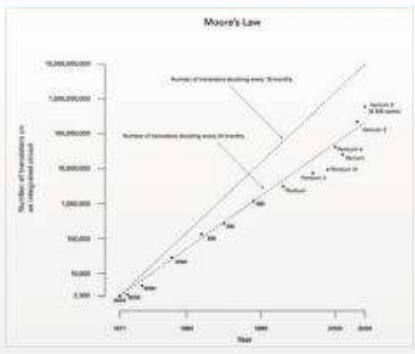
3 Add circuit
The circuit is transferred to a wafer. There are multiple circuits per wafer.

4 Trim excess
Any empty sections on the wafer are cut.

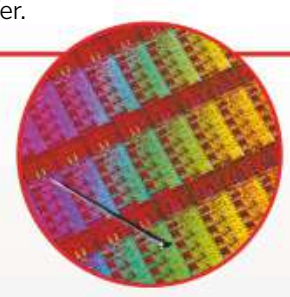
5 Terminals
The circuit terminals are welded on.

6 Plastic shell
Finally the protective plastic casing is mounted.

2005
Moore's law reaches its 40th anniversary as processors emerge that contain hundreds of millions of transistors.



2011
Transistors start to be manufactured in super-tiny 22-nanometre processes en masse.



2012
Intel begins mass producing 3D transistors with its 22-nanometre process, naming them Tri-Gate transistors.

2013
Intel builds a new fabrication facility in Arizona, which is to make chips on a next-gen 14-nanometre process.

© Th nkstock; So 90; F x t.com

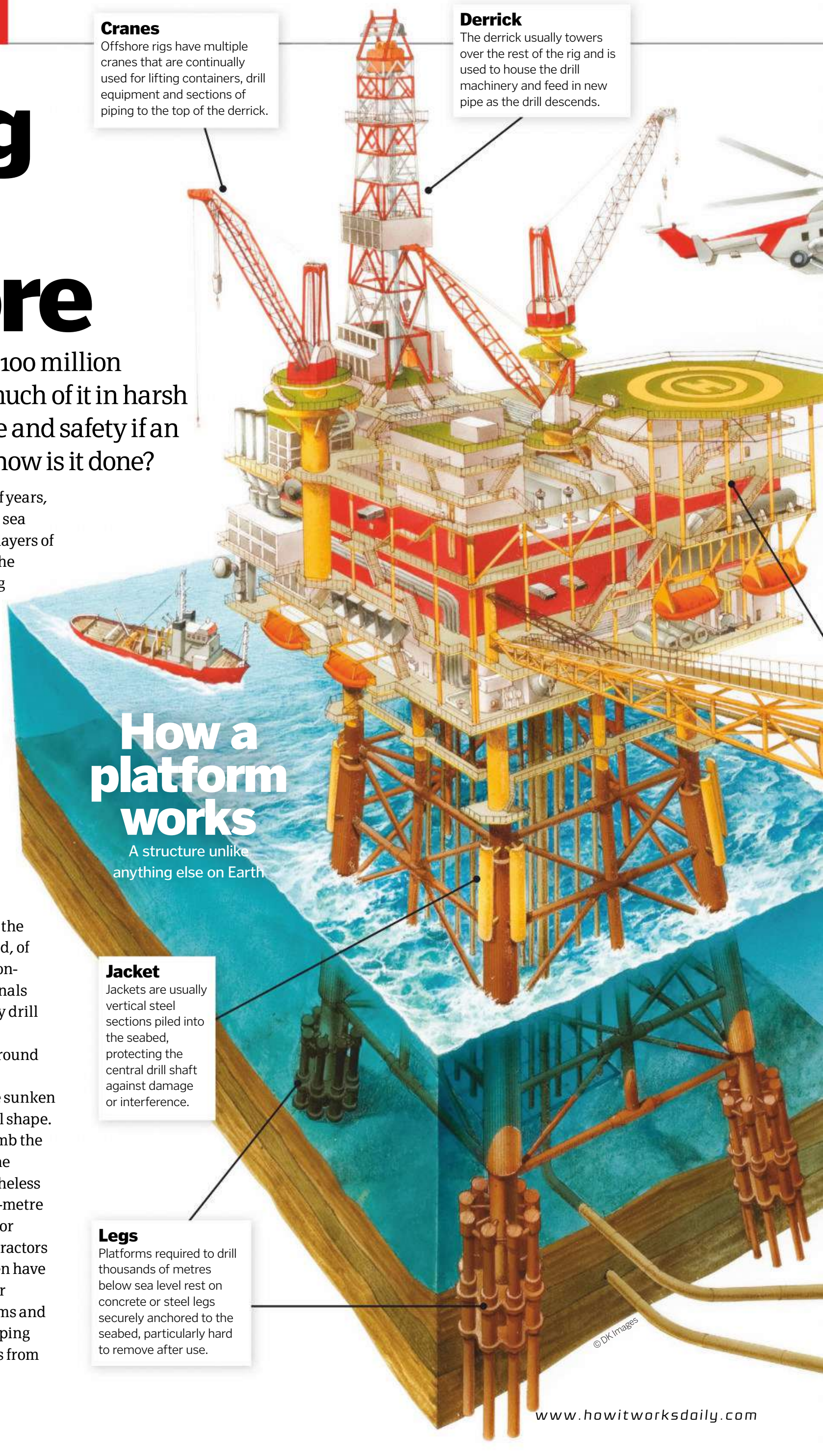
Drilling for oil offshore

The world produces over 100 million barrels of oil every day, much of it in harsh conditions, far from shore and safety if an emergency happens. So how is it done?

Oil has been around for millions of years, located deep below the land and sea where it became trapped under layers of permeable rocks or is slowly seeping to the surface. Although examples of oil drilling were documented in 4th-century China, the first modern oil-gathering structure was built in 1897, and by 1928 mobile rigs consisting of a simple barge with a drill mounted on top had set the scene for a revolution that fuelled Western industrial dominance for the next century.

Over 100 million barrels of oil are produced every single day, a process that usually starts with a range of surveys, from geographical and geomagnetic surveys to the deep echo sounding or seismic reflection surveys that pinpoint the likely location of a substantial deposit. Only then, and after the necessary permits have all been obtained, of course, can the rigs move in – multimillion-pound structures and teams of professionals that locate, make the well safe and finally drill down to its precious commodity.

Today there are over 40,000 oil fields around the world, with most offshore drilling undertaken in the continental shelf – the sunken perimeter of a continent's original glacial shape. From the $100 million monsters that plumb the deepest waters in the Gulf of Mexico to the smaller North Sea structures that nevertheless have to withstand 90-knot winds and 20-metre waves, mobile rigs are usually reserved for exploratory work, owned by private contractors and leased to the oil companies, who then have limited time to find, tap and process their precious bounty. Larger manned platforms and spars can service up to 30 wellheads, tapping into multiple wells up to eight kilometres from the platform itself.


Cranes
Offshore rigs have multiple cranes that are continually used for lifting containers, drill equipment and sections of piping to the top of the derrick.
Derrick
The derrick usually towers over the rest of the rig and is used to house the drill machinery and feed in new pipe as the drill descends.
How a platform works
A structure unlike anything else on Earth
Jacket
Jackets are usually vertical steel sections piled into the seabed, protecting the central drill shaft against damage or interference.
Legs
Platforms required to drill thousands of metres below sea level rest on concrete or steel legs securely anchored to the seabed, particularly hard to remove after use.
© DK Images

Life on an oil rig

Required to work for up to six months a year, oil workers are well compensated for the undeniably hazardous conditions they work in. Wages are typically higher than in similar engineering disciplines and the larger platforms and spars come complete with facilities more appropriate to a cruise ship than a floating factory. These can include private rooms for the 100-plus crew, cinemas, 24-hour restaurants and even gyms. Supplies are usually brought in by helicopter or ship, making oil platforms better stocked than most workplaces and significantly more important to the local economies they reside in. It is estimated that every offshore worker supports up to ten more in local industries such as food, transport or maintenance.

However, the dangers are constant and largely unpredictable. Offshore drilling involves not just dealing with highly flammable oil and gas, with the added danger of this being pumped out at exceptionally high pressures, but also extreme wind and sea conditions. When danger strikes, support is often miles away by helicopter or ship, and despite the high levels of training and increasingly safe equipment, offshore fatality rates have been on the rise in recent years. In addition to this, workers are often prone to alcoholism or drug abuse to overcome the isolation and gruelling 12-hour shifts.

Above: Accommodation decks of a North Sea oil platform
Below: A worker checks the drilling head on a tower

Deck
The working space aboard an offshore platform where drilling rigs, production facilities and crew quarters are located. Larger platforms may use nearby 'floatels' for crew quarters.

Wells
With each platform needing to service up to 30 wells at different depths and positions, flow lines and umbilical connections are required to connect them all to the main rig.

Oil rig teamwork

The men and women who make it all possible

Offshore installation manager
Also known as the man in charge (MIC) the installation manager makes all key production decisions, both before, during and after drilling. They have usually worked their way through the other drill team roles.

Driller
A highly specialist discipline, drillers are the ones that operate the drilling equipment, including making the initial hole in the seabed. They are effectively in charge of everything that happens on the rig floor.

Roughneck
The grunts of the oil business, roughnecks work in teams of three and are mainly responsible for manual work, both during and after drilling. They can also be called on to operate other equipment such as mud shakers.

Derrickhand
So called because of their position at the top of the derrick, derrickhands are usually working roughnecks responsible for the guiding of pipe into the drill as well as operating mud pumps and other such machinery.

Tool pusher
On an offshore rig, tool pushers tend to be department heads in charge of drilling or other essential functions such as engineering or operations. They may also assist with administrative work such as payroll or benefits.

THE RIGHT RIG FOR THE JOB

Drillships

Designed for speculative or deep-water mining, these vessels are converted to include a drilling platform in the centre. Drill ships use sophisticated sensors and satellite tracking to keep them moving while lined up to the well.

Semi-submersibles

Made up of floating pontoons and columns able to sink in the water where they are anchored to the sea floor or kept in place by steerable thrusters. Effective up to 1,800 metres, they're designed for quick deployment.

Jackup rig

Mobile platforms that can be raised on extendable steel legs. Designed for depths of 500 metres or less, they are useful for small to mid-sized deposits and typically only support smaller drilling crews.

Rig

An immovable structure of concrete and steel that rests on the seabed with deck space for multiple rigs, crew quarters and production facilities. Their design makes them ideal for large offshore deposits.

Spar

Perfect for major oil fields such as the North Sea, spars are drilling platforms fixed to giant, hollow hulls that can descend up to 250 metres. They stay still above the ocean floor and are secured by cables.

How automatic door mechanisms work

How do these doors know to open when you approach?

© Getty

As the most popular supermarket door choice, automation supports daily crowds that often leave with full hands

There's nothing more welcoming than a door opening for you. Without the need to be touched to open or close, automatic doors are essential in improving disabled access to buildings, facilitating hygiene in required areas and helping provide general convenience to commercial buildings.

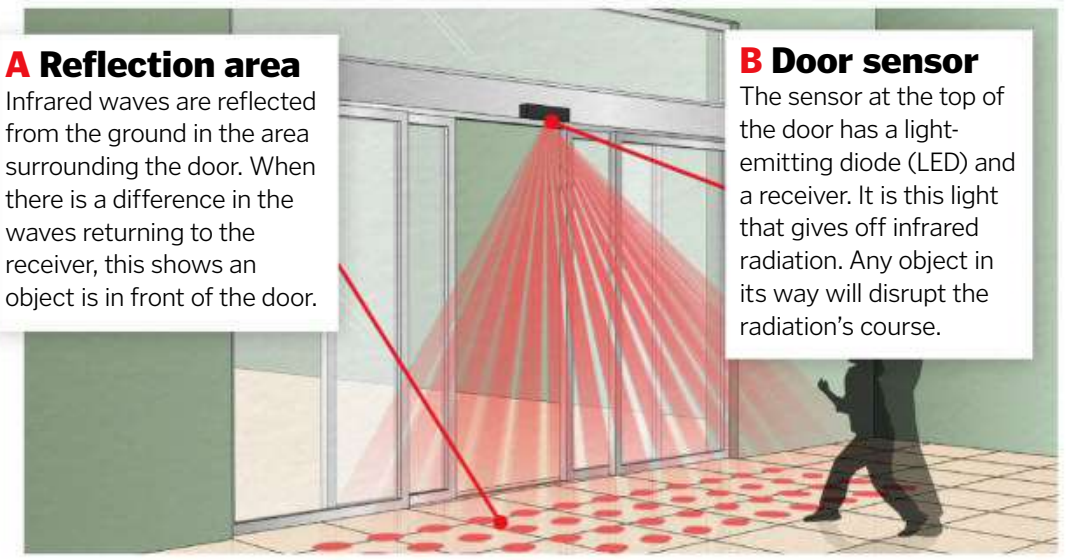
Self-sliding doors began to emerge as a commercial product in 1960 after being invented six years previously by Americans Dee Horton and Lew Hewitt. They started out as a novelty feature, but as their use has grown their benefits have extended within our technologically advanced world. Particularly useful in busy locations or during times of emergency, the doors act as crowd management by reducing the obstacles put in peoples' way. They give us one less thing to tackle during daily life and the occasional quick escape.

As well as making access both in and out of buildings easier for people, the difference in the way many of these doors open helps reduce the total area occupied by them. Automatic doors often open to the side, with the panels sliding across one another. Replacing swing doors, these allow smaller buildings to maximise the usable space inside without the need to clear the way for a large, protruding door.

There are many different types of automatic door, with each relying on specific signals to tell them when to open. Although these methods differ, the main principles remain the same. Each automatic door system analyses the light, sound, weight or movement in their vicinity as a signal to open. Sensor types are chosen to complement the different environments they are needed in. For example, a busy street might not suit a motion-sensored door, as it would constantly be opening for passers-by. A pressure-sensitive mat would be more appropriate to limit the surveyed area.

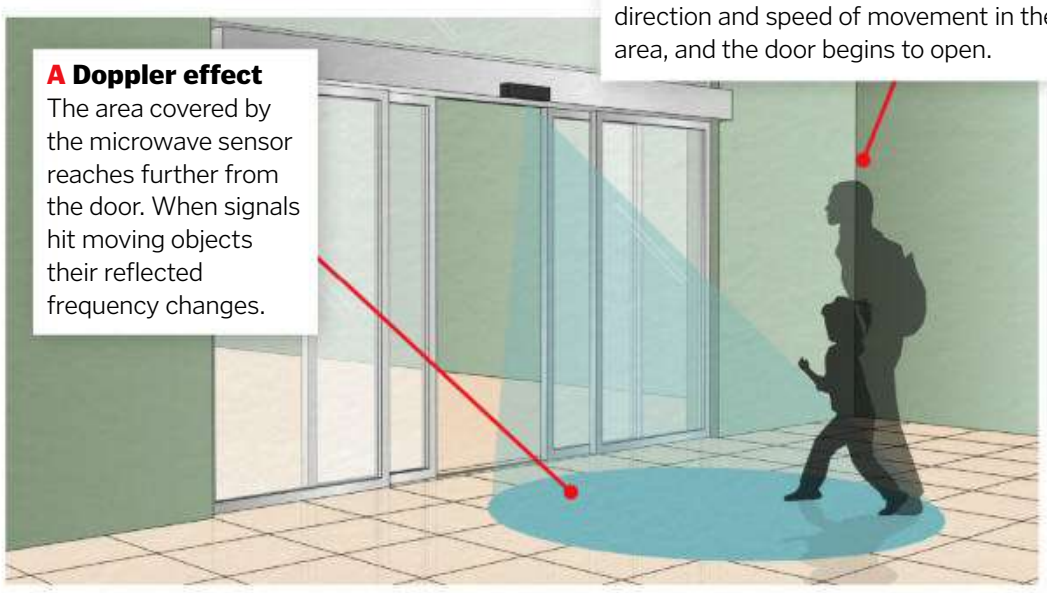
How different sensors work

In what ways can a door detect your presence?


A Reflection area
Infrared waves are reflected from the ground in the area surrounding the door. When there is a difference in the waves returning to the receiver, this shows an object is in front of the door.
B Door sensor
The sensor at the top of the door has a light-emitting diode (LED) and a receiver. It is this light that gives off infrared radiation. Any object in its way will disrupt the radiation's course.

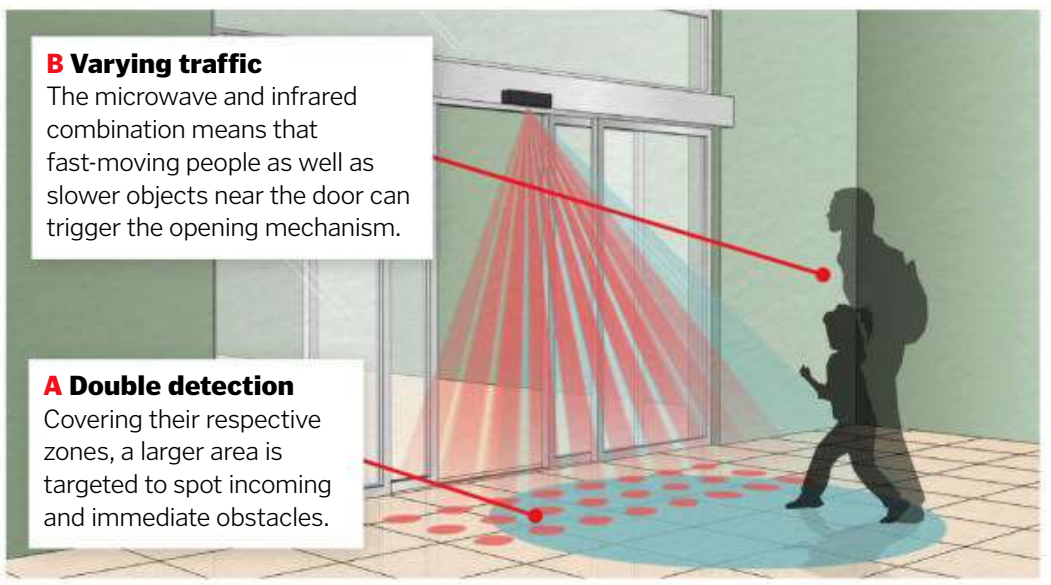
Active infrared

Everything that emits heat gives off infrared radiation, and it is the job of these sensors to detect it. Using infrared rather than movement makes the system suitable for detecting the heat of human bodies over other objects. Active systems give off and receive the wavelengths, differing from passive systems, which only receive.


A Doppler effect
The area covered by the microwave sensor reaches further from the door. When signals hit moving objects their reflected frequency changes.
B Walking speed
As someone moves towards the door, each reflected wave returns to the sensor in less time. This data corresponds to the direction and speed of movement in the area, and the door begins to open.

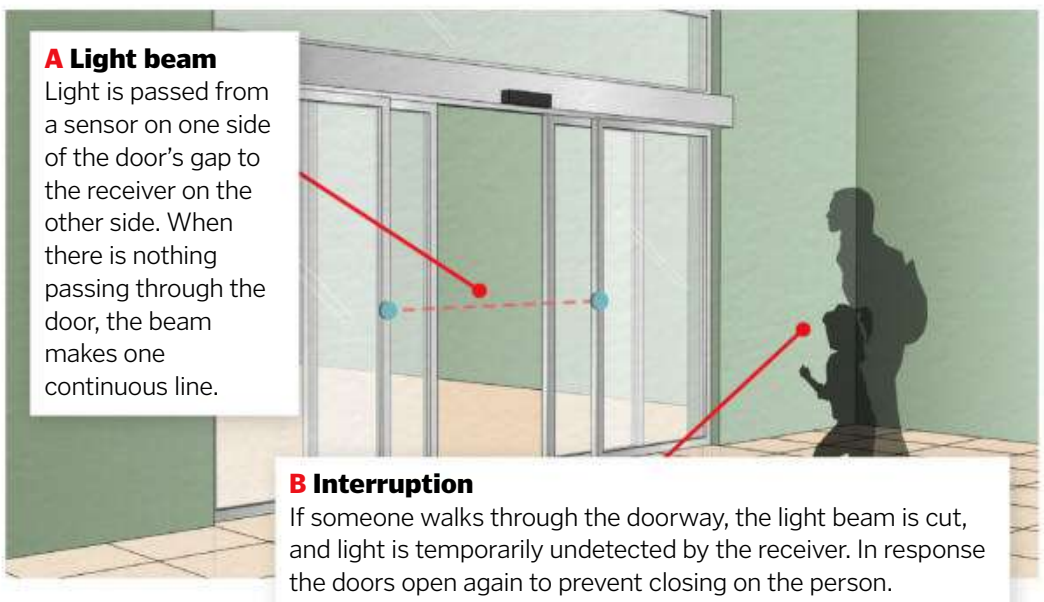
Microwave

Microwave sensors use electromagnetic radiation to detect any moving objects. Not only can they open when they sense movement, using microwaves means that the direction of travel can be pinpointed for improved accuracy.


B Varying traffic
The microwave and infrared combination means that fast-moving people as well as slower objects near the door can trigger the opening mechanism.
A Double detection
Covering their respective zones, a larger area is targeted to spot incoming and immediate obstacles.

Combined

Using both infrared and microwave technology increases the volume of data captured by the door. The combination of the two systems helps to improve accuracy and effectiveness, limiting the chances of standing in front of a door that won't budge.


A Light beam
Light is passed from a sensor on one side of the door's gap to the receiver on the other side. When there is nothing passing through the door, the beam makes one continuous line.
B Interruption
If someone walks through the doorway, the light beam is cut, and light is temporarily undetected by the receiver. In response the doors open again to prevent closing on the person.

Beam

This is one of the simpler automatic door mechanisms. Consisting of a beam of light, this acts as a safety feature, ensuring that the coast is clear when the door begins to return to its closed position.

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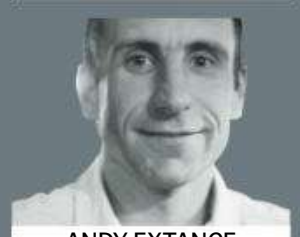
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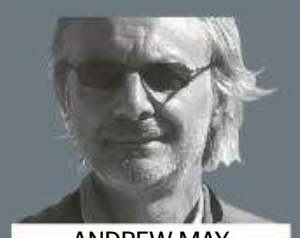
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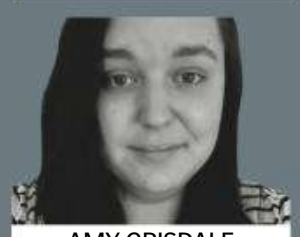
AMY GRISDALE

Sea lions need a third eyelid to shield their eyes from salty sea water and to keep the eyes moist when basking in the Sun

Want answers?

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Why do some animals have a third eyelid?

Alec Bruce

Birds, reptiles and some mammals have an extra eyelid to protect the eye from dust and dryness. Its technical name is the nictitating membrane. It has its own gland that generates up to half the tears an animal's eye needs. This is particularly important for birds to keep their vision sharp when flying high up. Unlike our eyelids, this secret bonus lid is translucent and sweeps left and right like windscreen wipers. **AG**

© Getty

The terrifying roar of the velociraptors in Jurassic Park was actually a recording of mating tortoises

© Getty

Do we know what noises dinosaurs made?

Frank Thompson

Dinosaurs lived and died 65 million years before humans even existed, so we'll never know exactly what they sounded like. We can deduce that dinosaurs made sounds of some description. Fossils show us that extinct reptiles had well-developed hearing. This trait probably wouldn't be so advanced if dinosaurs weren't communicating with sound somehow. Another clue is that some fossils have been found with rudimentary voice boxes. These were found to be extremely similar to certain families of modern birds, making scientists start to think that dinosaurs could've honked like geese. **AG**

© Getty

Why do UK MPs say 'hear, hear'?

Barry Simon

The expression is a shortened form of 'hear him, hear him!' and has been used by MPs from the 17th century onwards as a sign of agreement instead of applauding, which is generally forbidden in British parliament. **JE**

Why do cats push things off edges?

Jessie Blackburn

Cats are predators, and knocking things off the edge of a table is part of their hunting behaviour. The cat probes the object to see if it's dead. **AG**

© Getty

What if Napoleon had won the Battle of Waterloo?

Doug Jennings

Things would probably have turned out badly for the emperor even if he had won at Waterloo because another confrontation was fast approaching. A wave of 200,000 soldiers from Austria and Russia had been working their way across Europe in a bid to end Napoleon. Since he was running out of fresh troops the chance of a second successful battle would have been highly unlikely, and he would have most likely lost to Alexander I soon afterwards. **JE**

© Getty

Napoleon's success would not have lasted very long even if he had beaten Wellington

BRAIN DUMP

What's the most powerful rocket ever launched?

Erin Rogers

Surprisingly the answer to this question is the same today as it was 50 years ago – NASA's giant Saturn V rocket, which took the Apollo astronauts to the Moon. **AM**

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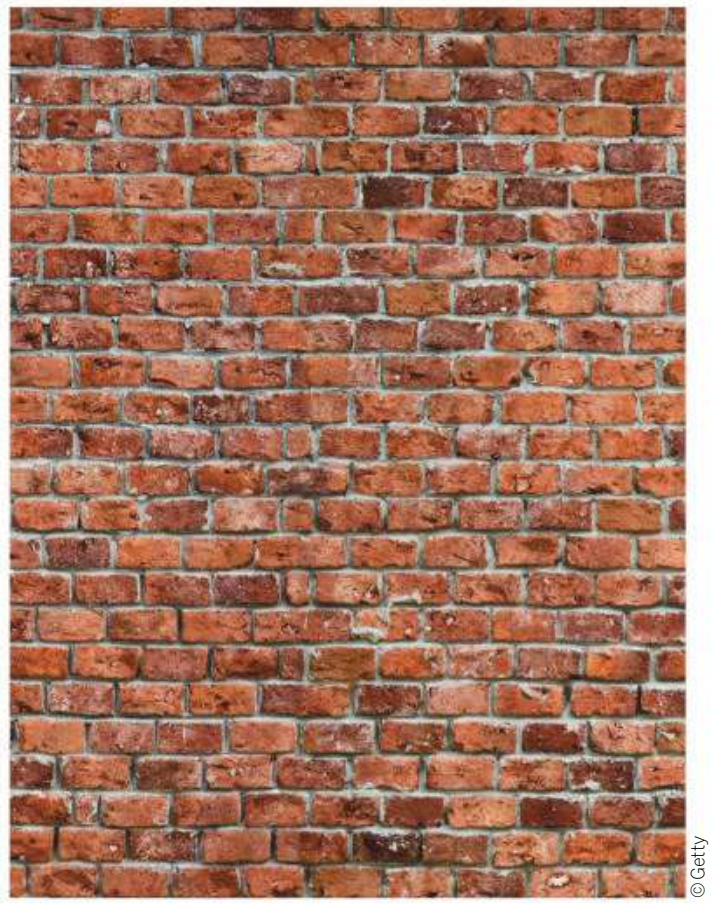

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Why are bricks orange?

Ralph Black

Bricks often have an orange colour because brick recipes include iron oxide. This is what iron forms when it rusts. But brick recipes also include clays and lime, which are natural substances whose chemical make-up can vary, giving different brick colours. **AE**

© Getty

What's a silkhenge?

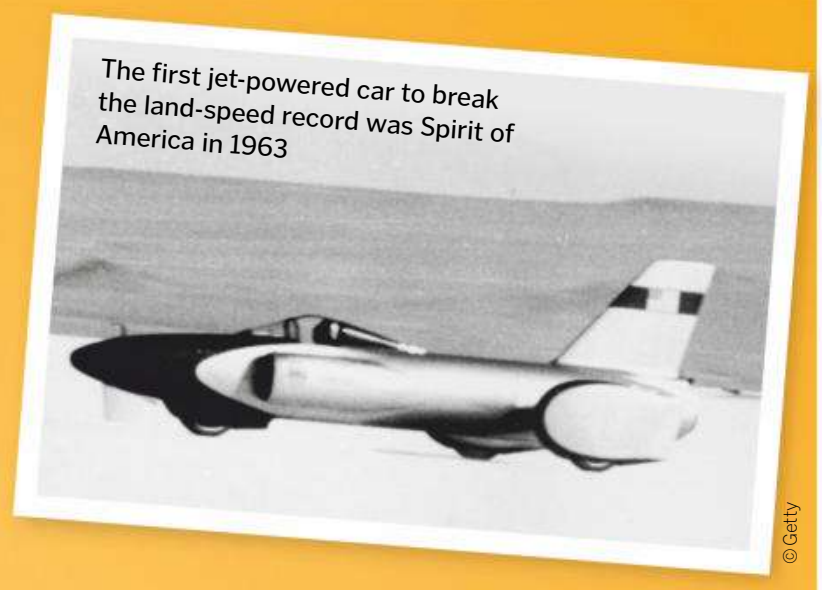
Louise DaSilva

Certain species of South American spider build charming web structures to protect their young. Hatchlings break out of the central orb while the spindles around the outside repel water and deter predators. **AG**

Could you use a jet engine in a car?

Conor O'Brien

In normal driving, cars need to turn sharp corners and change speed depending on traffic conditions. Engines that power the wheels through a system of gears are ideal for this. A jet engine, which works by producing thrust, is great for acceleration, but not for making sharp turns or an emergency stop. Jet-powered cars do exist, but only for things like drag racing and breaking speed records – they'd be useless for the morning commute. **AM**



The first jet-powered car to break the land-speed record was Spirit of America in 1963

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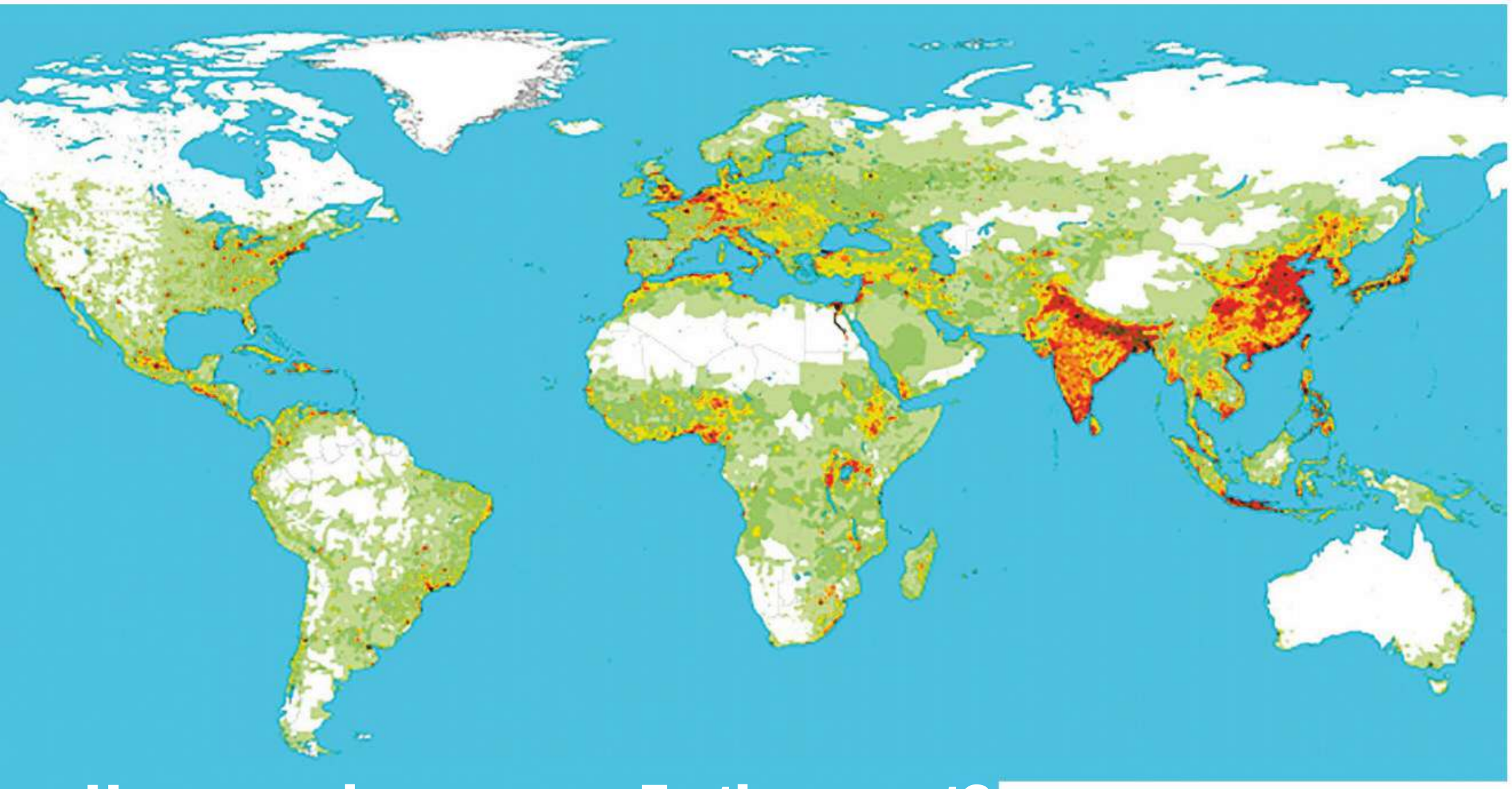

How many humans can Earth support?

Most scientists believe that Earth can support between 9 and 10 billion people – although some claim the carrying capacity is just 4 billion. That's quite a problem since the current world population is around 7.8 billion, and still growing every single day! **JE**

Why does the flesh of an apple turn brown so quickly after you bite into it?

Amy Ray

It's all to do with the biological machines known as enzymes in the apple's cells. When oxygen reaches injured plant tissue, enzymes called polyphenol oxidases whir into action. They start adding oxygen to some of the key flavour chemicals in apples, known as tannins. One more chemical reaction then makes new chemicals with the brown colour. The amount of this enzyme varies between apple species, and depends on how long the apple's been growing, so some go brown faster than others. You can slow the process by avoiding oxygen – like covering up chopped apples in water or sugar. **AE**

Biological machines quickly turn sliced apples brown by adding oxygen atoms to the fruit's flavour chemicals

© Getty

Why does my tongue heal so quickly after I bite it?

Tim Kasperek

Our saliva contains miracle molecules that mend wounds quicker than a scrape on our skin could heal. Histatin-1 is the name of a short amino acid chain in our spit that has a huge range of healing properties. It grows new cells to replace any damaged in an injury and helps them migrate to the site of the wound and cover it piece by piece. It even helps the body create new blood vessels to increase blood flow to the wound. **AG**

Even though saliva has miracle healing abilities, our mouths contain 700 species of bacteria, so licking a wound isn't necessarily going to help

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BOOK REVIEWS

The latest releases for curious minds

Astrophysics for People in a Hurry

But good even if you're not in a hurry

- Author: **Neil DeGrasse Tyson**
- Publisher: **Norton**
- Price: **£13.99 / $18.95**
- Release: **Out now**

Somewhere between research paper jargon and equations, Einstein wrote: "If you can't explain something simply, you don't understand it well enough." If there was any doubt that renowned astrophysicist and TV host Neil DeGrasse Tyson didn't really know his stuff before he wrote *Astrophysics for People in a Hurry*, then consider it removed.

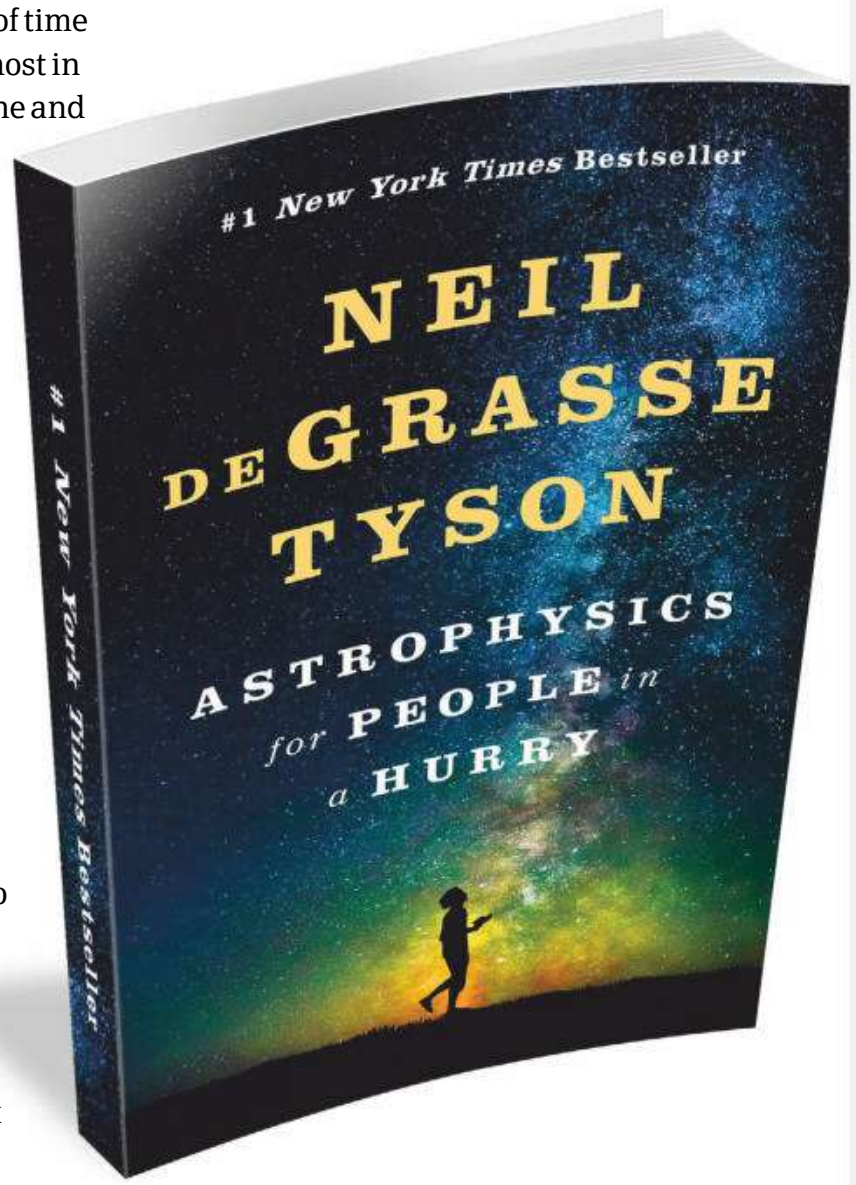
This book belies such a weighty and expansive subject – you could almost carry it around in your pocket. The font is large and double-spaced, and Tyson discusses some of the bleeding edge of astrophysics topics in a light, conversational style, as if he was kicking back in a comfy armchair and reeling off well-worn anecdotes. The birth of the universe and cosmic expansion, with its strange extremities of infinitesimally large space, tiny fractions of time and blistering energies, are discussed almost in the same chapter as the relatively mundane and accidental discovery of the cosmic microwave background by two telephone engineers in the 1960s.

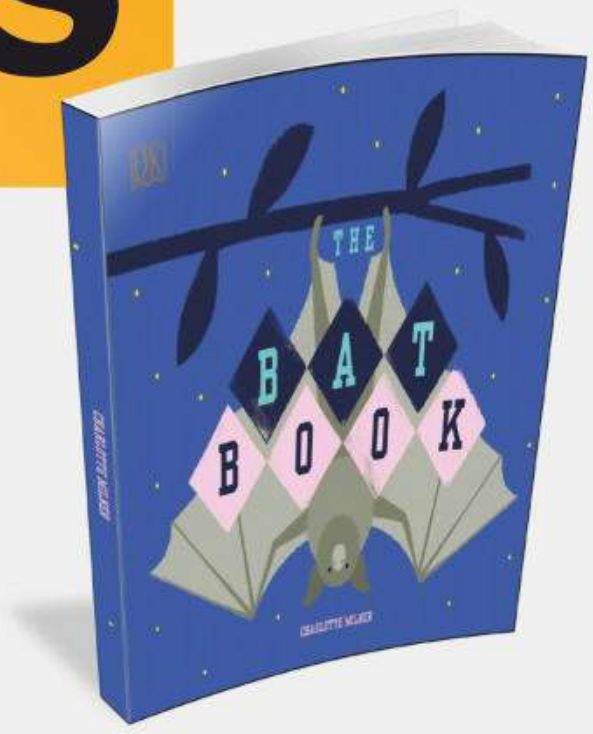
If we're going to be technical here, astrophysics blurs with cosmology and other academic fields, but we're not going to argue with Tyson on this subject. *Astrophysics for People in a Hurry* is the antithesis of a stuffy textbook or research paper, explaining the story of the universe in Tyson's inimitable, easy-going and engaging tone. You could zip through all 12 chapters in a single sitting – or perhaps a long train journey – but we think it deserves the respect of a dedicated read, rather than being crammed in to fill a couple of empty hours in a busy schedule. You'll certainly want to pause and digest some of the mind-boggling concepts Tyson deals with.

The RRP is a premium, but we suppose that reflects the entertainment and educational value that this little hardback offers. Whether you're an astrophysics initiate, expert or complete novice, there's something you can learn from reading *Astrophysics for People in a Hurry*; at the very least it's a lesson in how to take a subject that can read like wading through treacle and deliver it in an engaging, accessible and often funny package.

★★★★☆

> *This book belies such a weighty and expansive subject*





The Bat Book

Discover the secret world of bats

- Author: **Charlotte Milner**
- Publisher: **Dorling Kindersley**
- Price: **£12.99 / $15.99**
- Release: **Out now**

How much do you know about bats? As the only flying mammal, they take to the skies long after nightfall, making them difficult to spot, follow and explore. With this balanced book of text and visuals, readers can delve into a new and exciting world of the upside-down dwellers.

Every page carries a warming colour scheme – shattering the myth that bats are scary and shining light on these creatures of the dark in mesmerising detail. The attractive artwork draws you in to learn that these ominous animals carry a much greater purpose than their role as a spooky Halloween prop. Learn about every aspect of these winged wonders, from where they choose to hang to how they navigate through the dark nights. With elaborate close-up illustrations of curious characteristics and the varying bat species of the planet, this book proves that no two furry faces are the same.

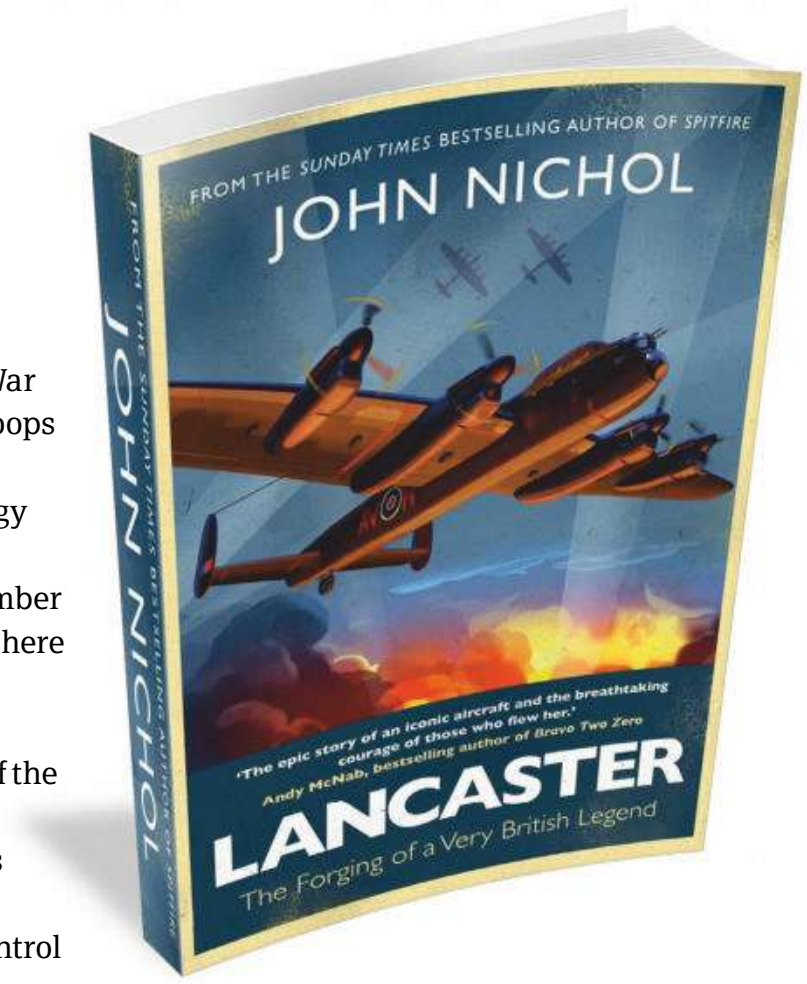
The Bat Book is a must-have for any animal lover between the ages of five and eight, taking them on a journey to understand the true importance of bats. Easily understood imagery helps explain their essential acts of plant pollination and how they provide for the environment. Not only are environmental and conservation issues portrayed in a child-friendly way, it even ends with an opportunity for the reader to embark on their own mission: helping bats to help the planet.

★★★★☆

Lancaster

Living aboard the bomber

- Author: **John Nichol**
- Publisher: **Simon and Schuster**
- Price: **£20.00 (approx. $24.50)**
- Release: **Out now**


FROM THE SUNDAY TIMES BESTSELLING AUTHOR OF SPITFIRE
JOHN NICHOL
'The epic story of an iconic aircraft and the breathtaking courage of those who flew her.'
Andy McNab, bestselling author of Bravo Two Zero
LANCASTER
The Forging of a Very British Legend

Flown by the Royal Air Force during World War II, the Lancaster bomber provided British troops with the extreme precision, impressive manoeuvrability and high-quality technology needed to carry out their duties. Many of us know the achievements of the Lancaster bomber through historical accounts, but this book is here to take the reader inside the plane using the captivating memories of surviving veterans. Enduring many hours cramped in the rear of the plane, join the missions through the eyes of Lancaster bomber's rear gunner Ron and his fellow comrades.

Following the stories of those who took control of these planes, author John Nichol explores what it was truly like to take off in these Lancasters and fly into the unknown. How did it feel to sit thousands of metres in the air as a flying target, not knowing whether you would ever make it safely back to land again? How can you watch your friends die and continue to be thankful? What can you do when things go wrong? The touching words of RAF veterans provide the greatest possible understanding.

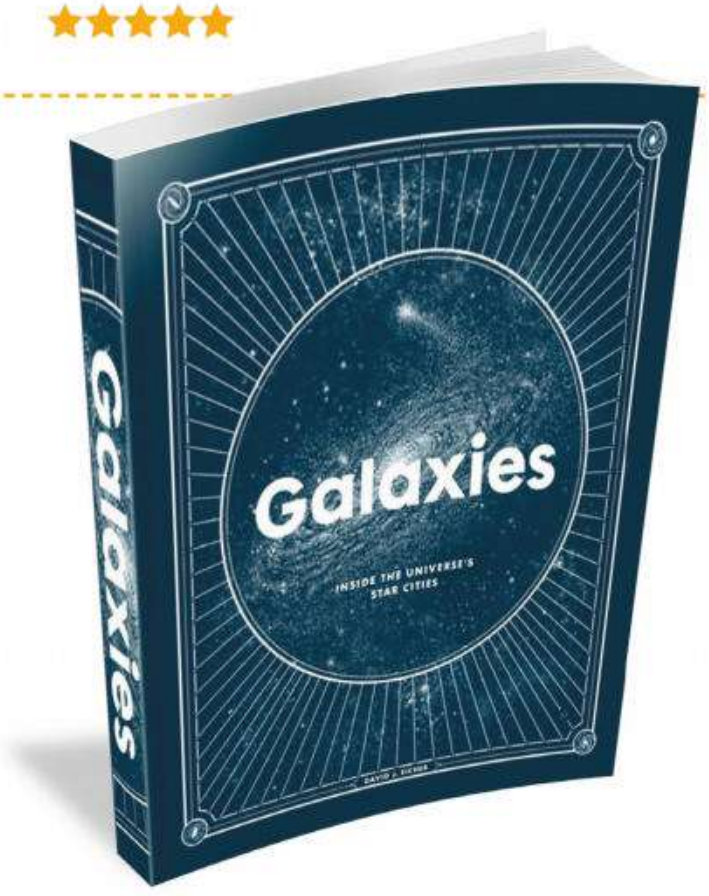
Lancaster takes you on a gripping ride of your own, as true accounts of bravery, determination, anguish and pride are told through vivid depictions. Not only does this book reveal personal hardships of this war, but demonstrates real gratitude for the simplest of life's beauties. Mixed in with the trauma, pain and sorrow, these pages pour with equal measures of love stories and companionship – above all it is a tribute to all who served aboard the Lancasters and those who aided them.

★★★★★

Galaxies

Explore the beauty of the cosmos

- Author: **David Eicher**
- Publisher: **Wildfire**
- Price: **£25 / $30**
- Release: **Out now**



Conceptualising the universe is an endeavour that many have attempted, and a multitude of authors have told the story of the cosmos in varying degrees of depth and insight. However, *Galaxies* by David Eicher has attempted to illuminate the wonders of the universe with both scientific prowess and visual appeal. Frankly, he has done an exceptional job. Seamlessly blending the complex science behind how our universe may have formed and the vast variations of the galaxies humans have observed, Eicher has created a book that celebrates the majesty of the universe and the galaxies within it. Filled with awe-inspiring photography and comprehensive illustrations, this book not only triumphs in its liability to inform its readers but presents astrophotography as an art form.

★★★★★

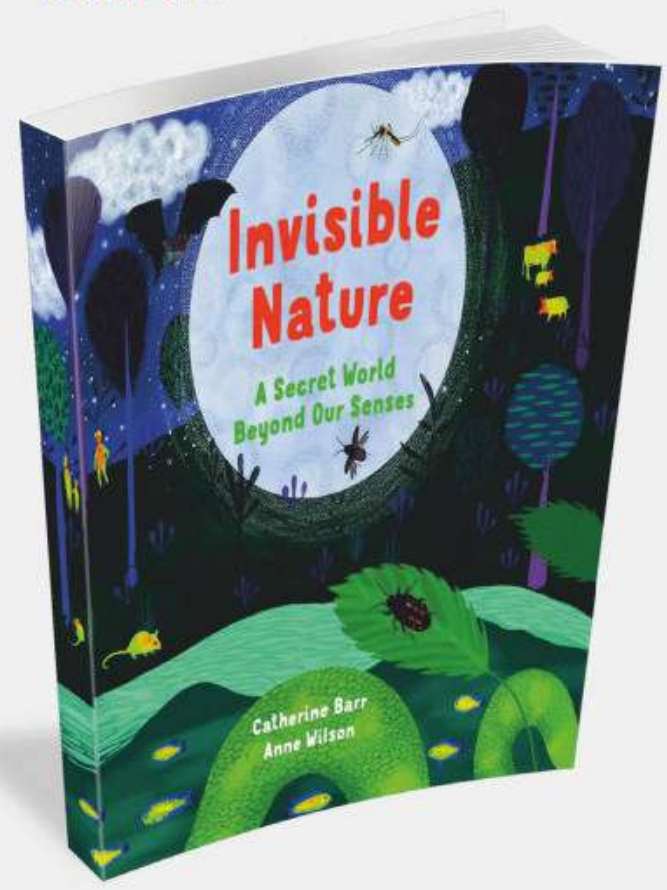
Invisible Nature

Discover the science of the unseen

- Author: **Catherine Barr**
- Illustrator: **Anne Wilson**
- Publisher: **Otter-Barry Books**
- Price: **£12.99 / $18.99**
- Release: **Out now**

Upon reading the title of this book, it might leave you puzzled as to its contents: what could invisible nature be? It turns out that what author Catherine Barr has created is a book that takes several principles in physics and relates them to their role in nature. Bursts of knowledge about how smell, magnetism, light and sound are vital to the everyday lives of Earth's animal and human residents make up the book's bitesize body text. Although laid out in a slightly repetitive format, overall it succeeds in delivering concise nuggets of interesting and fun information across each page, wrapped up in colourful illustrations targeted at a young audience.

★★★★☆



Wrapped up in colourful illustrations

BRAIN GYM

GIVE YOUR BRAIN A PUZZLE WORKOUT

QUICKFIRE QUESTIONS

Q1 Which is the biggest part of your brain?
- Cerebellum
- Cerebrum
- Hypothalamus
- Medulla oblongata

Q2 What is the average life span of a Greenland shark?
- Seven months
- 89 years
- 390 years
- 2,700 years

Q3 Who discovered the Rosetta Stone?
- Howard Carter
- Hitler's SS
- Indiana Jones
- Napoleon's soldiers

Q4 Where can you find the biggest storm in the Solar System?
- The Sun
- The asteroid belt
- Jupiter
- Pluto

Q5 What's the minimum time it takes for oil to form in the ground?
- 50 million years
- 100 million years
- 1 billion years
- 5 billion years

Q6 Which British banknote has Charles Dickens appeared on?
- 10 shillings
- £1
- £5
- £10

Spot the difference

See if you can find all six changes between the images below

Sudoku

Complete the grid so that each row, column and 3x3 box contains the numbers 1 to 9

EASY

8		9	1		7	2	4	
2	4				9	7		6
1				5				3
7		1	5		8	4		
9		8					6	
3	2				1	8	5	9
	9	3	7	8	5			1
	8				6		9	
		2				5	7	

DIFFICULT

4		1	5				6	
	5							
	7					2		8
8		2					9	7
					2	3		
5				8	1			
	2		4		7		1	
		7	8	3				5
	3							

What is it?

Hint: This minibeast is a vital visitor to gardens around the world...

A .....

S	O	L	A	R	O	Y	Z	A	U	F	O	W	I	R
U	B	X	N	A	C	P	E	H	K	I	D	R	T	S
M	C	A	N	Y	O	N	S	E	L	E	W	A	B	I
I	L	I	C	E	N	H	C	G	E	D	F	I	P	A
R	Q	O	S	U	M	J	A	P	O	T	Y	N	O	R
A	F	Q	P	X	E	D	P	H	N	I	K	F	A	N
D	V	A	U	N	O	M	E	I	O	C	L	O	N	E
S	T	F	I	O	S	B	A	C	I	P	J	R	D	I
O	X	G	U	A	N	H	G	A	T	O	F	E	P	Y
M	N	E	R	Y	E	E	K	S	U	C	B	S	H	D
E	V	F	I	C	K	E	P	A	L	E	E	T	E	T
L	B	U	G	X	C	N	I	Y	O	A	V	A	N	Q
O	S	P	A	T	I	A	L	A	V	O	K	C	G	O
U	J	A	Q	N	D	E	H	X	E	A	P	R	O	F
C	A	L	U	Z	O	E	P	O	C	S	E	L	E	T

Wordsearch

FIND THE FOLLOWING WORDS...

IQ
SPATIAL
EVOLUTION
RAINFOREST
CANYON
DICKENS
ESCAPE
CLONE
TELESCOPE
SOLAR
ENGINE
OIL

Check your answers

Find the solutions to last issue's puzzle pages

SPOT THE DIFFERENCE

QUICKFIRE QUESTIONS

Q1 Blue whale
Q2 Autism
Q3 1,300 psi
Q4 Arctic
Q5 Mercury and Venus
Q6 175 years old

WHAT IS IT? ...A GEODE

WIN!
A 3D PRINTER

This month we are giving you the chance to win an MP Cadet 3D Printer by Monoprice. WiFi and app-enabled, this countertop 3D printer is great for beginners

WORTH OVER £200!

For your chance to win, answer the following question:

Which of the following was ***not*** written by Charles Dickens?

a) **Oliver Twist** b) **A Christmas Carol** c) **Pride and Prejudice**

Enter online at **howitworksdaily.com** and one lucky winner will win!

Terms and Conditions: Competition closes at 00:00 BST on 2 July 2020. By taking part in this competition you agree to be bound by these terms and conditions and the Competition Rules: www.futuretcs.com. Entries must be received by 00:00 BST on 02/07/2020. Open to all UK residents aged 18 years or over. The winner will be drawn at random from all valid entries received, and shall be notified by email or telephone. The prize is non-transferable and non-refundable. There is no cash alternative.

DON'T DO IT ALONE
IF YOU'RE UNDER 18, MAKE SURE YOU HAVE AN ADULT WITH YOU

Get in touch
Send your ideas to...
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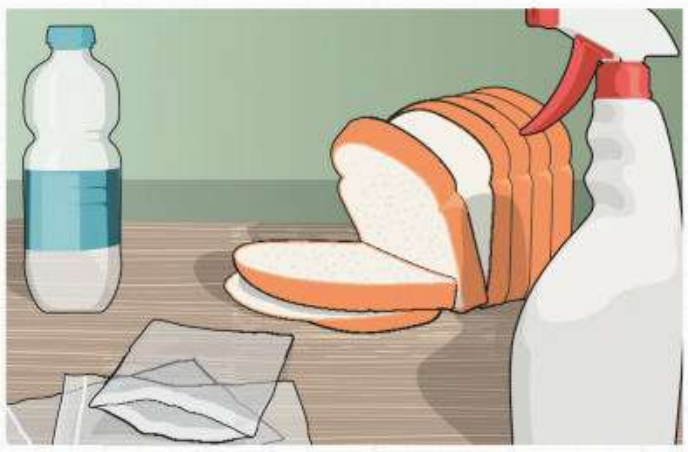
@howitworks@futurenet.com

How to see how dirty your hands really are

Discover how much hidden dirt is on your hands and household items

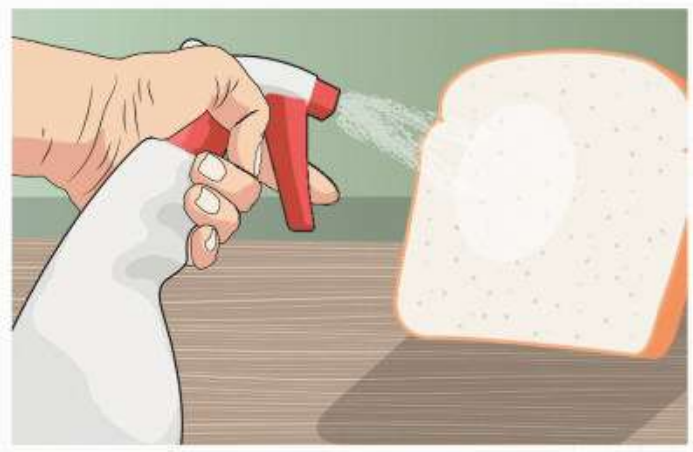


1 Gather your equipment

You will need the following items: bread slices, water, sealable plastic bags, a spray bottle, and dirty hands. The number of slices of bread you will need depends on how many objects you wish to test. For this example you will need three. A fresh loaf will work quicker as sliced bread from a shop often contains preservatives.

2 Wipe the bread

Wipe your hands on one slice. Make sure you touch the bread with the inside of your fingers, as this is where dirt can hide. Wipe another slice on your phone or laptop. For the third, use someone's hands who has just used hand sanitiser, to see how it compares. These can be swapped with any item you want to test, but remember what you wiped with each slice.

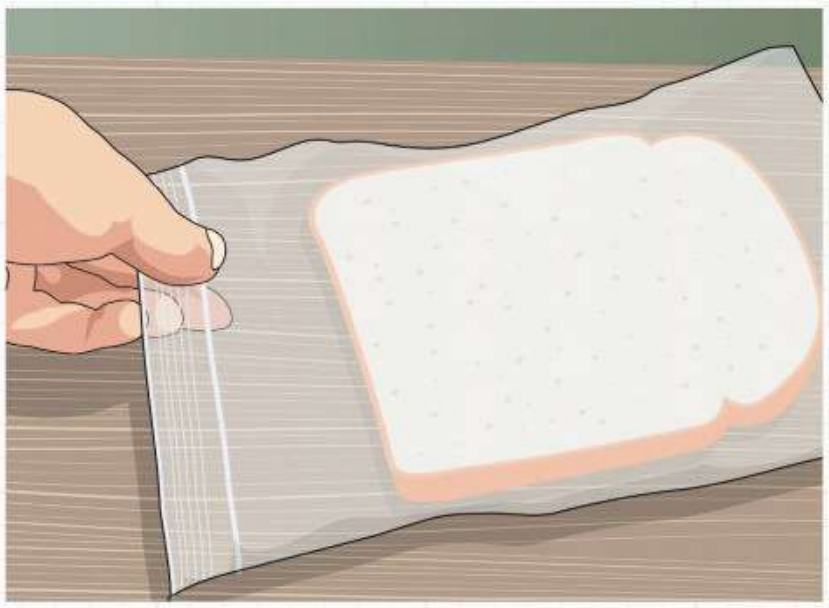


3 Spray the bread evenly

Once you have wiped the bread slices, spray them with a light coating of water. This will help the mould grow quicker as it thrives in damp environments. Spray each slice once or twice, but keep the number of sprays consistent across all slices. If you don't have a spray bottle, you can sprinkle a light covering with your hands, keeping it as even as possible.

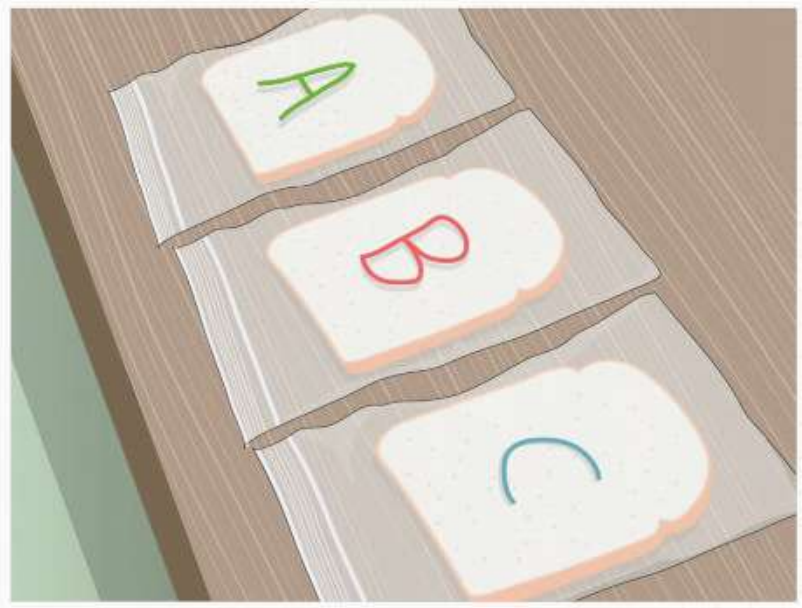
4 Make sure the bags are sealed

Place each slice into a separate plastic bag or container and make sure to seal them tight. This will keep the mould growing inside and will keep you safe from exposure.



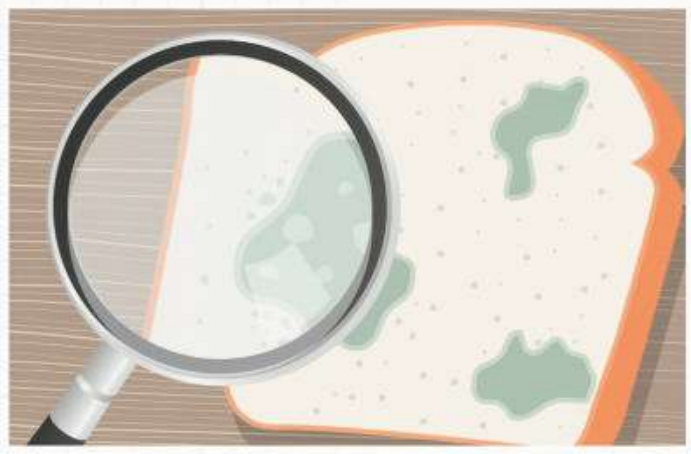
5 Label the samples

Label each bag with the item it was wiped on. This is so you know which slice was wiped on which object when you observe the results later. You can also write down your predictions at this point to look back on afterwards.



6 Store the bread

For the best mould growth, store the bags of bread somewhere warm. Along with the moisture in the bag, this will provide the perfect warm, damp growing conditions. The mould doesn't need sunlight, as all the food it needs can be sourced from the bread.



7 Observe the mould

Check the progress of the growth daily and see when it starts to appear on each slice. Significant growth should be seen after just seven days. Were your hands as clean as you thought? When you have finished with the experiment, safely dispose of the bread without opening the bags.

SUMMARY

The mould that grows on the bread is a visual representation of the dirt you cannot see lingering on your hands, between the keys of your keyboard or on any object you wiped the bread on. By touching the bread, this shows how easily bacteria, viruses and mould spores can be transferred onto other objects. Watch how the mould growth compares to the bread touched by hands cleaned with soap and water or sanitiser to discover the importance of washing your hands.

Had a go? Let us know!
If you've tried out any of our experiments – or conducted some of your own – then let us know! Share your photos or videos with us on social media.

NEXT ISSUE
How to make a tornado in a bottle

© Illustrations by Ed Crooks

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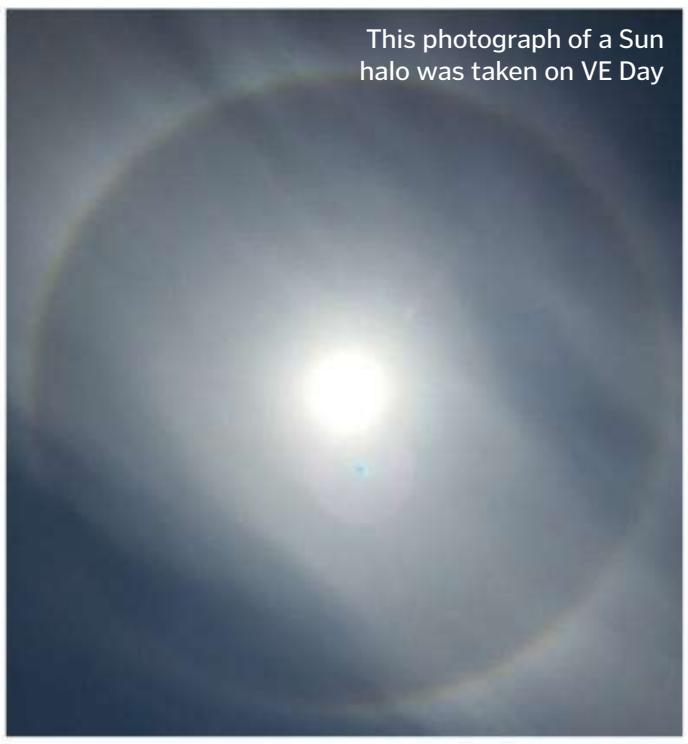
INBOX
Speak your mind...

Get in touch
If you have any questions or comments for us, send them to:

How It Works magazine @HowItWorksmag howitworks@futurenet.com



This photograph of a Sun halo was taken on VE Day

© Sebastian Sprankling

VE Day Sun halo
Hi **HIW,**

I am very excited to tell you of an amazing phenomenon I saw on VE Day when trying to spot the scheduled Spitfire. When I looked into the sky, instead of a plane I saw a rainbow circling the Sun! After reading **HIW** I knew that this sort of event was caused by ice crystals in the upper atmosphere. What a coincidence that I was looking into the sky at that moment! I was lucky enough to take some mythical-looking pictures before the clouds ruined the halo.
Sebastian Sprankling, aged 10

This photograph from Sebastian shows the impressive phenomenon that is known as a Sun halo. These halos are usually seen when there are thin clouds very high in the sky. Being at this height causes ice crystals to form, which reflect and refract the light to create this halo of light.

Thank you for showing us your photo. This is a great reminder that nature can offer us some of the most fascinating displays at the most unexpected moments at a time when many events have been cancelled. After reading about it, we are glad you were able to see this halo effect in real life.

Haynes

WIN! THREE HAYNES MANUALS

From cars, to space shuttles, to Milliennium Falcon: Haynes guides take all sorts of vehicles apart and shows the reader exactly how they work, how to maintain and to repair them.

Letter of the month

Graphics project
Hi **HIW,**

We had to recreate a **HIW** cover page with a new idea and by remaking the logo for a graphic design project! I'm a huge fantasy nerd and had the idea of making a tabletop game issue. With everything going around with the quarantine and people being inside, it's the perfect time to reconnect with friends online with Dungeons and Dragons!
Bandit (@bandit.ai)

Thank you for sharing your graphics assignment with us. We think this How It Works-style cover would make a fantastic issue for any games lover, and your choice of imagery really grabs attention. Filled with tips and tricks for the game, this issue could definitely help Dungeons and Dragons fans to get stuck in while spending time away from their friends. We hope you get good marks for your project!

This specialist magazine artwork was created for a graphics assignment

© Bandit

Bitter-sweet
Hi **How It Works team,**

A few days ago I had half a very sharp white grapefruit. I put the other half which had not been prepared in a clear box, with the wet side down, in the fridge. Today I found the box with the grapefruit in it and it looked exactly the same but it was much sweeter. Is this a one-time occurrence or is there an answer as to why it was so much sweeter?
Martin (12)

P.S. Loving the magazines, especially the fascinating cuts through everyday objects to see what's inside. Keep up the good work!

Thank you for your interesting question. Usually grapefruit only change in sweetness when they are growing and ripening on the tree. Once picked they maintain their bitterness. However, seeing as you ate the first half of the grapefruit a few days before the second and left the grapefruit with its protective peel removed, this may have caused some changes in taste. Once cut, the air that the grapefruit segments are exposed to can start to dry out the fruit. This reduces some of the intense flavour that the grapefruit has. It may not have been that the bitterness had changed, but that the strength of flavour had, making it seem less bitter.

Sometimes a temperature difference in food changes how your taste buds perceive the bitterness. Being cold fresh from the fridge could have taken the edge off the bitter taste you remembered from before. Lastly, any food you ate just before the grapefruit can change how you taste it. If you had just eaten something sweet, the contrast in flavours alerts your taste buds and brings out the intense bitter sensation.

Once cut, grapefruits keep for longer in the fridge

© Pixabay

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NEXT ISSUE...
Issue 140 on sale
9 JULY 2020

Love and heartbreak

Hi **HIW,**

I bought my first edition of your magazine this month, intrigued by the article on heartbreak. I believe the initial definition of heartbreak as the experience of rejection is much too narrow because death is then cited as one of the causes. I certainly don't see death as rejection or a 'downfall of love' and I take issue with linking these, or at least the link for me wasn't very clear. Isn't death and heartbreak more to do with the loss of love, whatever the cause or form it takes?

Lynn Muldrew

© Pixabay

Issue 137 explored the positive and painful sides of love

Thanks for getting in touch. In a recent issue we explored the impact of love on the body. As part of this we looked into the effects caused when a relationship with a loved one changes or ends. Heartbreak covers a range of situations and severities. Rejection was used to refer to one of the acts that can lead to heartbreak, but does not define all elements of it. The comparison showed being rejected from a relationship during the early stages of love to the unexpected loss of someone you love and everything in between – but no two can bring exactly the same feelings or physical responses. The 'downfalls of love' referred to the times when love is anything less than the perfection often associated with it.

One of the medical examples used was broken heart syndrome, which is a serious response of the body often caused by a more intense loss. This syndrome has occurred in those dealing with the heartbreak that comes with losing a loved one, as well as other examples that were used in the feature. While rejection, betrayal, loss and death were all examples behind heartbreak following love, they were not meant to be interchangeable.

Sanitiser science

@mixedscientist: Little scientist is getting ready to make his colourful hand sanitiser.

Thanks for sharing this picture with us of your son making his own hand sanitiser, as seen on our previous issue's 'How to' page. Not only did you make your own useful hand gel, but you put your own spin on it to make it a colourful creation with food dye. We were pleased to hear that it went well and you enjoyed making it. It's the perfect time for home experiments!

© @mixedscientist

One of our readers made his own alcohol-based hand sanitiser

What's happening on...

social media?

This month on social media we asked you: 'What is the strangest animal you have ever seen?'

@scimaxfacts

A giant locust. It was weird because it looked like a cricket but was the size of my shoe!

Cathal Bergin

One of the strangest, and most beautiful, must be the snow monkey! I saw them on David Attenborough's new documentary

@sunnah_safdar

A coypu!!! Saw one in Germany, looks like a beaver/ otter and we had no idea what it was!

HOW IT WORKS

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FAST FACTS

Amazing trivia to blow your mind

65%

YOU'LL REMEMBER TWO-THIRDS OF A PIECE OF INFORMATION THREE DAYS LATER IF IT'S A PICTURE

390 BILLION

THE AMAZON RAINFOREST CONTAINS A STAGGERING NUMBER OF TREES

100

BEFORE THEY BEGIN TO FUSE, BABIES HAVE MANY MORE BONES THAN ADULTS

42 YEARS

ENGINEER JACK KILBY INVENTED THE INTEGRATED CIRCUIT IN 1958, BUT DIDN'T WIN THE NOBEL PRIZE FOR IT UNTIL 2000

3%

VERY FEW ANCIENT EGYPTIANS KNEW HOW TO READ AND WRITE HIEROGLYPHS

BABY ELEPHANTS COMFORT THEMSELVES BY SUCKING THEIR TRUNKS

YOUR BRAIN IS MORE CREATIVE WHEN YOU'RE TIRED

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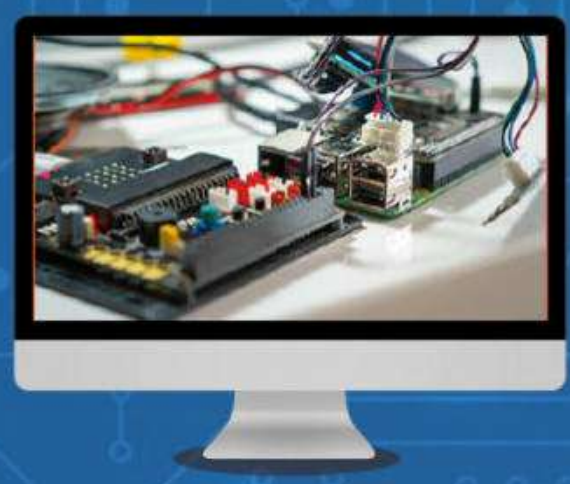

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